THE FLORAL RESOURCES OF NEW SOUTH WALES OF PRIMARY IMPORTANCE TO COMMERCIAL BEEKEEPING

Douglas Charles Somerville

A thesis submitted for the degree of
Doctor of Philosophy
at the Australian National University

October 2004

DECLARATION

The research presented in this thesis is my original and independent work.

Specific contributions and assistance by others are referred to in the text and acknowledgements.

Doug Somerville

Doug Somerville
October 2004

ACKNOWLEDGEMENTS

There are a number of people and organisations that have substantially contributed and assisted me in conducting these studies. Primarily I am very grateful for the support and love shown to me by my wife Annette and children, Robbie and Heather. I have had to balance working full time with my strong commitments to family, plus completing the various stages of my research over the last seven years, I thank them very much for their support.

I am especially grateful to Graham Kleinschmidt (former lecturer and researcher, University of Queensland, Gatton campus and past chairman of the honey bee program within Rural Industries Research and Development Corporation) and Mike Moncur (former floral biologist and senior research scientist, CSIRO, Division of Forestry, Canberra) for their keen and enthusiastic support, guidance and encouragement, also for agreeing to be on my PhD supervisory panel.

I thank Dr Chris Tidemann (School of Resources, Environment and Society, ANU) for agreeing to be the chair of my supervisory panel and supplying me with valuable advice and guidance through my studies and dealings with ANU. The experience has been interesting and rewarding. I am very grateful to the late Doug Boland (CSIRO Forestry, Canberra) who made up the fourth member of my PhD supervisory panel and demonstrated a keen interest in my studies, giving up his time to assist me in the guidance of my research.

One of the most important persons in my process of being able to complete such a large body of research and produce quality reports was Joanne Ottaway (clerical officer, NSW Agriculture, Goulburn). Thank you Joanne, for assisting and preparing most of the reports necessary to complete such research. I would also like to acknowledge other NSW Agriculture support staff who have assisted in various ways, including Vicki Saville, Jane Harris (clerical officers), and Liz Wilkes (librarian).

Much of the research in this thesis would not have been possible without funds provided by the Rural Industries Research and Development Corporation for two projects including the floral resource database survey (Chapter 4) and the analysis of honey bee-collected pollen (Chapter 7). Thank you to Dr Jeff Davis (program manager) for facilitating this process.

For specific projects I thank the following: Floral Resource Database Survey—Dr Gavin Melville (biometrician, NSW Agriculture), Dave Freckleton (Geographic Information Systems, NSW Agriculture), Bev Morcombe (data entry, NSW Agriculture), and to the 319 beekeepers who responded to this survey/census; Pollen Project—Wendy Peasley (chemist, NSW Agriculture), Maurice Kerr (chemist, Agriculture Victoria), Helen Nicol (biometrician, NSW Agriculture) and the 39 beekeepers who assisted in the collection of pollen.

I am grateful to Don Nicholson (State Forests, Dubbo) for the support and encouragement in initiating beekeeping activity studies of all the State Forest districts within NSW. In most cases these were conducted with individual State Forest foresters which included Ian Barnes (Batemans Bay), Steve Bishop (Kempsey), Steve Campbell (Narrandera), Chris Colley (Nowra), Mick Cooper (Morisset), Andrew Croft (Bathurst-Oberon), Steve Dodds (Narooma), Tania Hoffman (Wauchope), John Murray (Grafton, Urunga and Taree), Erica Raper (Eden-Bombala), Richard Rienstra (Inverell), Ian Robertson (Casino), Rod Shannon (Queanbeyan-Badja), Anthony Signor (Gloucester-Walcha), Mike Thompson (Central Murray Valley), Paul Wells (Forbes), and Mick Wilson (Dorrigo).

Thank you to Bill Winner (beekeeping services manager, Capilano Honey Ltd), for organising the honey delivery data based on species for their NSW suppliers. I would like to thank Des Cannon, (commercial beekeeper) for supplying me with his records and production data to provide a case study for Chapter 2.

I thank my fellow work colleagues for their professional support and encouragement—Dr Michael Hornitzky (research scientist, EMAI, Camden), John Rhodes (extension officer-apiculture, Tamworth), Murray Spicer (program leader, Orange) and Bruce White (technical specialist-apiculture, Windsor). Finally, I wish to thank NSW Agriculture, my employer, for allowing me the latitude to carry out such research and the support to finish the task.

ABSTRACT

Through various research techniques the floral resources of primary importance to commercial beekeeping interests within New South Wales (NSW) were established. Each method placed a different emphasis on what it is that was being evaluated. Surveys were probably the best method of encompassing all the aspects considered by beekeepers to be important pertaining to floral resources. The aspects considered of primary importance included nectar secretion, ultimately measured by honey produced, and the nutritional impact of pollen collected by honey bees on the colony.

A survey of all commercial beekeepers registered with the NSW Government under the Apiary's Act 1985 produced an 81% response. A total of 51 floral species were identified to be of primary importance to beekeepers. The top 10 listed in order were *Echium plantagineum, Eucalyptus melliodora, E. paniculata/E. siderophloia, Corymbia maculata/C. variegata, Brassica napus, E. macrorhyncha, E. camaldulensis, E. sideroxylon, E. albens* and *Trifolium repens*. A total of 238 floral species were mentioned by beekeepers as important to their beekeeping business.

In the State survey there was evidence of Victorian beekeepers periodically utilising flora within NSW, moreso than NSW beekeepers utilising flora within Victoria, also the same north/south movement on the Queensland border with NSW beekeepers tending to utilise flora north of the border moreso than Queensland beekeepers relying on the floral resources within NSW. The total honey production per colony increased with the number of hives managed by each beekeeping business from 41 kg/hive for operations managing less than 200 hives, to a peak of 111 kg/hive for operations managing between 801 and 1000 hives.

It was calculated that there were 23,479 apiary sites in NSW, with private property being the most important land tenure with 13,981 sites. The next most important land tenure was State Forests with 5,365 sites, and travelling stock routes and reserves with 2,972 sites. The least important in relation to the number of sites utilised on a State perspective was the National Parks and Wildlife and Crown Lands with 412 and 749 sites, respectively.

A series of surveys of beekeepers with occupation permits for the use of State Forest sites indicated a heavy reliance on *Eucalyptus* and related species. The number of apiary sites on private property adjacent to State forests amounted to 34% of the total number of sites utilised by beekeepers with colonies able to forage on the floral species within State forests.

The measurement of honey delivered by beekeepers to Australia's largest honey packer, Capilano Honey Ltd., provided strong evidence for the worth of species to beekeepers within NSW. The top 10 most important species from the honey delivery data collected over an eight year period, in order of volume, included *Echium plantagineum, Eucalyptus melliodora, E. ochrophloia, E. albens, Corymbia maculata/C. variegata, E. paniculata/E. siderophloia, Lophostemon confertus, Brassica napus, Trifolium repens* and *E. microtheca*. Not all honey delivered to Capilano was able to be identified, thus the amount of honey recorded against each species may be greater in some cases.

The single most important floral species was *Echium plantagineum* with 8,278,971 kg delivered over an eight year period, with the next most important floral species *Eucalyptus melliodora* with 3,890,205 kg delivered over the same period. Eucalypts and related species contributed 67% of the total honey delivered. The box and ironbark eucalypt bark types accounted for 55% of the total eucalypt and related species group. This has significant ramifications in the nutritional management of honey bees as both these two groups of eucalypts were regarded as poor providers of pollen which will negatively impact on the health and productivity of a colony.

The chemical analysis of 177 samples of honey bee-collected pollens represented the single largest collection thus far tested. Based on crude protein % of the pollens, the samples were able to be identified as low, medium or high quality pollen sources. There was strong evidence that similar chemical profiles existed between floral sources of the same genus. There was also a general deficiency in the essential amino acid, isoleucine, within the *Eucalyptus* genus.

Sixty one samples of *Echium plantagineum* pollens were collected from 30 separate sites over three years. The analysis of these pollens indicated locational differences and, to a lesser degree, year differences. The variation of the chemistry of the samples was not significant enough to change the quality rating of this source of pollen and affect its general nutritional contribution to developing honey bees.

Large differences were found in honey bee-collected pollens from floral species for fat and mineral content. The significance of these differences is not known and it was not possible to relate this information to the worth of any particular floral species in relation to its contribution to honey bee nutritional requirements.

There were a few discrepancies between the ratings by beekeepers of a floral species as a source of pollen and the chemical analysis of the pollen. The reasons for this were not clear, although one possibility was the low volume of pollen collected by honey bees from the species rated of low value by beekeepers. Further research is necessary on the subject of honey bee nutritional requirements and the chemical content of pollens collected by honey bees to better understand the importance of specific floral species to the wider NSW beekeeping industry.

All three research techniques utilised in the study support the value of *Echium plantagineum* as the most important floral species to NSW commercial beekeepers. The three techniques: surveying beekeepers; bulk honey delivery data; and chemical analysis of honey bee-collected pollens, link together to provide a strong indication of the most important floral species of importance to NSW commercial beekeepers.

TABLE OF CONTENTS

PAGE

FIGURES

TABLES

PLATES

CHAPTER 1

GENERAL INTRODUCTION

The purpose of this study was to identify the principal floral species of importance to the New South Wales (NSW) beekeeping industry. In the process, providing data on the chemical composition of honey bee-collected pollens, the relative merits of individual floral species for honey production, the distribution and phenology of the principal floral species identified in the study including information on the size and scope of commercial beekeeping within NSW. This will assist the scientific community, future researchers and reviewers to better understand the relationship between honey bees (*Apis mellifera L.*) and the flora of NSW.

All flowering plants are not equal in value for nectar and pollen production. Nectar is the primary source of carbohydrates and pollen satisfies the remaining nutritional requirements of honey bees including protein (amino acids), fat (lipids), vitamins and minerals. These two floral products collected by honey bees vary significantly in their quality, quantity and seasonal availability (Goodacre 1947; Clemson 1985). This variability experienced by a honey bee colony largely dictates the population dynamics of that colony and ultimately the potential productivity in relation to honey production.

The readers attention is drawn to the glossary for explanation of beekeeping terms used throughout this thesis, refer to Appendix 1. Where possible, botanical names were applied to floral species, although information was provided by beekeepers using common names for Chapters 2, 4, 5 and 6. Appendix 2 provides a glossary of botanical names and their common names. The principal reference for botanical names was the Royal Botanic Gardens (Anon. 2004).

With an understanding of the phenology of the floral resources within the operational range of a beekeeper, informed strategies can be formulated as to the management practices necessary to maximise honey bee populations in a colony coinciding with a major nectar flow from a targeted species. Without at least a basic understanding of the floral species that are of value in relation to the quality and quantity of nectar and pollen available and time of year these species are likely to be in flower, the resultant honey production obtained by beekeepers will be more a product of accident, rather than that of a well managed strategy to maximise production from a honey bee colony.

On a local basis, individual beekeepers are aware of the spatial, temporal and nutritional variability of flora as it impacts on honey bee management, although discussions with individual beekeepers indicate that even this knowledge is not necessarily homogeneous in any given region. Combining information collected from various sources allows a more comprehensive understanding of the complexity of the floriferous systems within which NSW beekeepers operate.

Chapter 1 provides background information to provide the reader a sense of the scope, variables, values and issues affecting beekeepers in NSW, and why this research is important. In addition an individual beekeeper's operation is examined in Chapter 2 providing detail highlighting the yearly decision making process and evidence why beekeepers migrate between flowering events. There will be significant annual differences between a honey bee colony managed and transported to target nectar and pollen sources throughout the year, as compared to a colony left in a static location. Chapter 3 is a review of literature pertinent to the spatial, temporal and nutritional variability of the floral resources of NSW, with reference to honey bees.

Chapters 4 and 5 document the results of various surveys conducted on a large proportion of the State's commercial beekeepers. Data on honey delivery from NSW suppliers to Australia's largest honey packing company is provided in Chapter 6. This data illustrates the value of various floral species as a function of total honey delivered. The nutritive value of honey bee collected pollens is discussed in Chapter 7 with the protein, amino acid, fat and mineral data from 182 pollen samples.

In Chapter 8 the survey data will be discussed with the results of the previous chapters to ascertain the value of floristic species as major sources of nectar and/or pollen. The survey results will be discussed with the pollen data in Chapter 7 to indicate the value and importance of various species for their contribution to the nutritional management of honey bees. In the context of this thesis, nutritional management refers to the contributions of protein, amino acids, fat and minerals to the dietary requirements of honey bees. The following background information on honey bee biology and the NSW beekeeping industry is provided as an introduction, providing the reader with an understanding of the context of the various sets of data presented in subsequent chapters.

Honey bee biology

A colony of honey bees is a complex social system made up of three distinct types, or castes of bees. Female bees are either queens or workers and the males are drones. Usually there is only one queen in a normal honey bee colony with a population of a few thousand to sixty thousand worker bees. The queen is the only fertile female in a colony and as such her main function is to produce viable eggs for the ongoing population replenishment of the colony. Drones may range in number from zero to a thousand individuals. Drones are usually only present in the spring and summer, although if fresh nectar and pollen continues to be available they may be present in a colony through the autumn and possibly winter periods. The function of drones is to mate with virgin queen bees prior to the queen commencing egg laying. Workers, by their very name, provide the work force for the colony fulfilling various functions including building comb, nursing young larvae by cleaning cells and feeding developing larvae, grooming and feeding the queen, feeding drones, foraging for nectar, pollen, water and propolis, and defending the colony (Winston 1992).

The life span of a queen may vary from one year to several. This is dependent on the egg laying rate that she may have to sustain over time and the volume of sperm stored in her spermatheca as a result of her initial mating flights (Laidlaw and Page 1996). The life span of a worker bee is primarily dependent on the amount of work she is expected to perform. During cool winter periods worker bees may live for many months, in a tight cluster formation within the hive, maintaining a suitable temperature to prevent freezing. A sister female worker born in late spring may live only two to five weeks due to the work load being placed on her (Winston 1992). The lifespan of a worker bee will also be influenced by the quality of the diet received in its larval stage. Lower quality pollens amount to reduced longevity whereas high quality pollen in adequate quantities ensure worker bees reach their maximum genetic longevity (Kleinschmidt 1986).

The colony population at any given date is dependent on the fertility of the queen, the dietary intake of the colony, temperature/climate and the prior population. Young vigorous queens are able to start egg laying earlier than older queens and sustain a higher egg laying rate. This egg laying is usually stimulated by fresh nectar and pollen gathered from the surrounding flora within flying range of the hive. Warmer temperatures are also considered an inducement for a colony to be stimulated to increase in population. The available number of nurse bees restricts the rate at which a population can increase due to the limitations of feeding a reduced number of larvae and maintaining the correct hive temperature (Laidlaw and Page 1996).

For the purposes of this study the reader should be aware of the following:

- The larger the colony population the greater the proportion of field honey bees surplus to collect nectar and pollen.
- This population is in part dependent on the quality of pollens consumed in the larval stages of development.
- High protein content in pollens will maximise longevity of the individual honey bee and thus increase its working/foraging life.

Thus, for a beekeeper to manage honey bee colonies to maximise honey yields per hive, they should ensure that colony populations are maximised prior to a nectar flow and that a colony has access to high nutritious pollens during the population building phase to ensure long lived honey bees once a nectar flow is in process (Kleinschmidt *et al.* 1974; Kleinschmidt and Kondos 1976).

Beekeeping in New South Wales

Honey bees were first introduced into NSW in 1810 (Weatherhead 1986; Barrett 1995), although the beekeeping industry as we know it today probably had its beginnings in the 1940s (Goodacre 1947). The advent of better roads and the ability of beekeepers to shift hives by horse and dray and later by truck to desirable nectar flows, expanded production. This has grown to an industry that can and does shift honey bee colonies the length and breadth of NSW and across State borders to pursue reliable nectar and/or pollen sources.

The NSW beekeeping industry is the largest of any of the Australian states, producing 45% of the Australian honey crop. Australia produces approximately 30,000 tonnes of honey each year of which 9,000 to 12,000 tonnes is exported (Gibbs and Muirhead

1998). The major markets are the United Kingdom, Germany and Singapore. In 1992 Australia was rated as the ninth largest producer of honey in the world (Australian Honey Board 1992). Minor products occasionally produced by some specialist apiarists include propolis, pollen, royal jelly and bee venom. Beeswax is a by-product of honey production and is produced as a result of the honey extraction process. The major contribution of honey bees to the wider community is through their role as pollination agents for a significant number of horticultural and agronomic crops. Honey bees are used in NSW to pollinate a range of crops, particularly apples, pears, cherries, plums, kiwifruit, strawberries, blueberries, rockmelons, watermelons, almonds, lucerne, faba beans, cotton, sunflower, white clover and canola. Pollinating insects, of which honey bees are the significant majority, contribute between $604 million to $1.2 billion annually to the Australian economy (Gill 1989). Without the actions of honey bees, many crops would not be profitable.

There were approximately 4,500 registered beekeepers in NSW in 1996, managing approximately 250,000 hives. Beekeepers can be divided into hobbyist, semi-commercial or commercial. The majority of honey is produced by the commercial beekeeping sector, with the average producer operating 350 to 700 hives (Hornitzky *et al.* 1993). In 1996, 400 beekeepers maintained more than 200 hives, representing 200,000 hives in total (Somerville 1999a). Commercial beekeeping operations are largely family operated and are based in the major and minor rural centres across the State.

The majority of NSW beekeepers in the commercial sector operate hives for the production of honey. Average honey produced per hive for NSW producers has been stated as 120 kg per annum (Hornitzky *et al.* 1993). The hobbyist keeps honey bees for recreation and quality of life purposes (Fogarty *et al.* 2000). A small group of beekeepers keep honey bees for pollinating their own fruit trees or small areas of crop. The semi-commercial or "sideline" beekeeper usually manages hives in an opportunistic fashion which requires a certain investment in capital but reduced hive numbers limit income. Specialist beekeepers producing queen bees or other products such as propolis, pollen, royal jelly and bee venom may manage reduced numbers of hives, as the labour requirements could be substantial.

The major differences between mainland Australia and other countries are the diverse range of eucalypt species and our variable climatic conditions. Even though much of NSW has a distinct winter, spring, summer and autumn period, the flowering of different species will vary from year to year based on the cycle of growth and budding. Drought conditions have a major impact on the flowering patterns of eucalypts. Thus, in any given 12 month period, beekeepers in NSW are unlikely to be working the same flora and the rewards honey bees obtain from flowering events are critical to the success of commercial beekeeping operations in NSW (Clemson 1985).

For a commercial beekeeper to maintain a viable business, it is necessary to maximise productivity per hive. To achieve this can be quite a challenge, given the need for a detailed knowledge of the flowering patterns of Australian flora and the way that floral rewards impact on the management of honey bees. Given that many beekeepers are prepared to move apiaries over significant distances, sometimes in excess of one thousand kilometres, it is possible in many years to locate a species suitable to harvest nectar and pollen over a 12 month period. This, in essence, is the difference between NSW beekeepers and their overseas counterparts who operate beekeeping enterprises on a very defined annual cyclic flowering pattern based on the local flora. (New Zealand–Winter 1975; England–Carreck 1997; Switzerland–Gyger 1997; Canada – Gruszka 1998).

Generally, overseas, long winters restrict flowering events to six months of the year with reduced options to move apiaries, whereas in NSW, the combination of species which the beekeeper decides to place their hives nearby will vary from year to year according to what is to flower. It is this annual complexity or variability that necessitates different management strategies and makes it difficult to profit from commercial beekeeping unless one has a significant knowledge of what is flowering, where it is flowering, and what impact the floral rewards nectar and pollen from each flowering event will have on the management of the apiary.

In essence, the nomadic behaviour of NSW beekeepers will be based on what flowering events are predicted. For example, apiaries based on the coast in the late winter may be moved onto *Brassica napus* (Canola) in the cropping areas of the Central West in the spring to provide breeding conditions to increase colony population, or alternatively, they could remain on the coast where herbaceous plants would provide pollen and a light nectar flow to also achieve the same or similar population increases (Clemson 1985). They may then be moved onto a late spring honey flow, such as *Echium plantagineum* (Paterson's curse) in the Central West (Industries Assistance Commission 1985). This could be followed by further moves over summer depending on the availability of other flowering events. During autumn there is a range of species that could be viewed as options including *Eucalyptus macrorhyncha* (Red stringybark) on the tablelands or *Corymbia gummifera* (Red bloodwood) on the coast. In some years, there are opportunities to work winter nectar sources, particularly in the Western division or on the coast where warmer weather prevails. If no winter flowering events are available, the hives are left with sufficient stored honey to survive until the spring.

Knowledge of flowering events may also benefit government policy makers, public land managers, researchers and ecologists by increasing the understanding of how commercial beekeepers operate in NSW. A study of the floral resources important to beekeeping, particularly a review of floral species of value to beekeeping may benefit studies of other nectarivorous fauna in the Australian ecology (Eby 1995), such as birds, insects, flying foxes and other nectar-feeding mammals.

Threats to floral resource availability

Various land tenures, e.g., those managed by State Forests and National Parks, are placing considerable pressure on beekeeping mainly through restricted access to conserved lands. This is only one concern to beekeepers accessing floral resources. A more complete list of concerns to the floral resources applicable to the NSW beekeeping industry includes:

1. Government policy in relation to beekeeping on conserved lands (Somerville 1998a, 1999b).
2. Land clearing for agriculture (Breckwoldt 1986).
3. The felling of timber for firewood.
4. Forestry activities such as removal of mature high value nectar yielding honey trees.
5. Forest plantations – pines are not a beekeeping resource and many preferred eucalypt species selected for plantations have a low value for nectar and pollen yields.

6. Retardation of plant growth as a result of fire. This causes abortion of buds in eucalypts and seriously reduces the nectar and pollen yielding capacity for five to seven years in heathlands (Somerville 1998b). In extreme cases the vegetation is killed.
7. Reduced regular flooding of *Eucalyptus camaldulensis* (River red gum), reducing bud initiation (Somerville 1998b).
8. Salt inundation affecting the health of flora (Breckwoldt 1986).
9. Dieback, which seriously reduces the capacity of eucalypts to initiate buds and yield nectar when flowering (Breckwoldt 1986).
10. Droughts, which interrupt growth and flowering cycles.
11. Biological control of weed species that are of major benefit to honey bees, e.g. *Echium plantagineum* (Paterson's curse) (Industry Assistance Commission 1985).
12. Cultivars of agricultural crops which vary in their ability to yield nectar, e.g. *Brassica napus* and *B. campestris* (Szabo 1982; Mohr and Jay 1990; Kevan *et al.* 1991).
13. Urban sprawl and rural subdivisions are an increasing problem in removing mature vegetation and reducing the number of physical sites available for commercial apiaries, particularly near some coastal vegetation types. This is compounded by the conflict of having large numbers of commercial honey bees near populated areas.

Honey bee nutrition

It is important to understand honey bee nutritional management in the Australian context to allocate values to various floral species. Honey bees primarily collect two substances to satisfy their nutritional requirements—nectar and pollen. Nectar provides a carbohydrate source which is converted into honey in the hive and stored for later consumption, or it is removed, extracted and traded by beekeepers. Pollen is primarily the protein source and, although collected in lesser quantities, is arguably more important for the sustained longevity and survival of the colony. Pollen is the male germ produced by the anthers of the flower. The nutritional quality and quantity of pollen varies significantly between species (Kleinschmidt and Kondos 1976; Rayner and Langridge 1985; Muss 1987; Stace 1996a). The data presented in this thesis will assist in qualifying some of the values on pollen acquired by beekeepers over a number of generations. Experienced beekeepers are well aware that some species produce pollen which enables colonies to increase in population, ensuring that they are subsequently capable of producing significant honey crops. Some pollen sources do not stimulate population increase or the adult honey bees are shorter lived. This could be due possibly to poor quality pollen, i.e., protein levels below 20% and/or deficient in one or more amino acids, or insufficient quantity even though nectar is freely available (Kleinschmidt and Kondos 1976). The colony may die in these circumstances as a result of lack of a protein source for the bees to continue breeding (Clemson 1985).

There have been numerous attempts by beekeepers in Australia and overseas to create an artificial pollen substitute (Somerville 2000a). This has not been entirely successful for the complete composition of pollen has not been analysed and the dietary requirements of honey bees has not been satisfactorily determined. Enquiry continues in this area and the evidence collected in this research will help support that endeavour.

The art of commercial beekeeping is to ensure that all colonies are of sufficient population to maximise nectar collection and thus honey production. Substantially increasing the population of a colony may require three or four weeks, or three or four months, depending on the early availability of nectar, pollen, favourable flying conditions and the original population of the colony. Once an expanded population has been achieved, the hives are moved onto a nectar (honey) flow. The nectar flow may be supported by a good (quality and quantity) pollen supply or it may not. If the pollen was of a poor quality or low in quantity the worker honey bee population would be sacrificed as there are fewer replacements in proportion to the mortality of field honey bees. The aim of the beekeeper is to manage a hive to increase the colony population prior to working a major honey flow. Often the population is reduced during a major nectar flow, therefore at the end of a flowering event colonies would again be managed to increase the population prior to the next major nectar flow (Kleinschmidt *et al.* 1974). Understanding what constitutes good breeding conditions, adequate nectar and sufficient quality pollen to build up colony strength prior to a major nectar source is of interest in this study.

To illustrate some of the complexities of beekeeping, the following case study of a commercial beekeeper is presented in Chapter 2. This will provide an example of the use of various floral species illustrating the impact of drought and the variety of flora utilised by a commercial beekeeper based on the NSW Southern Tablelands.

CHAPTER 2

CASE STUDY: Bilga Honey Supplies

The following information provides an insight into the range of floral species considered of primary importance for the management of honey bee colonies in one circumstance. This will assist in highlighting the complexity of the decision making process most commercial beekeepers in NSW are exposed to.

Bilga Honey Supplies is owned and managed by Des Cannon with assistance from partner Jenan Cannon. The operational base is located on a 'bush block' twenty minutes drive, east of Queanbeyan in the Southern Tablelands of NSW. The historical beginning of Bilga Honey was in 1978 with the purchase of one hive. Figure 2.1 illustrates the growth in the number of hives managed up to the year 2000. For the period 1978/79 to 1983/84 Des Cannon could be categorised as a hobby beekeeper. From 1984/85 to either 1987/88 or 1991/92 the number of hives managed equates to a part-time commercial sized operation. From 1992/93 onwards the number of hives managed would be considered a commercial sized operation.

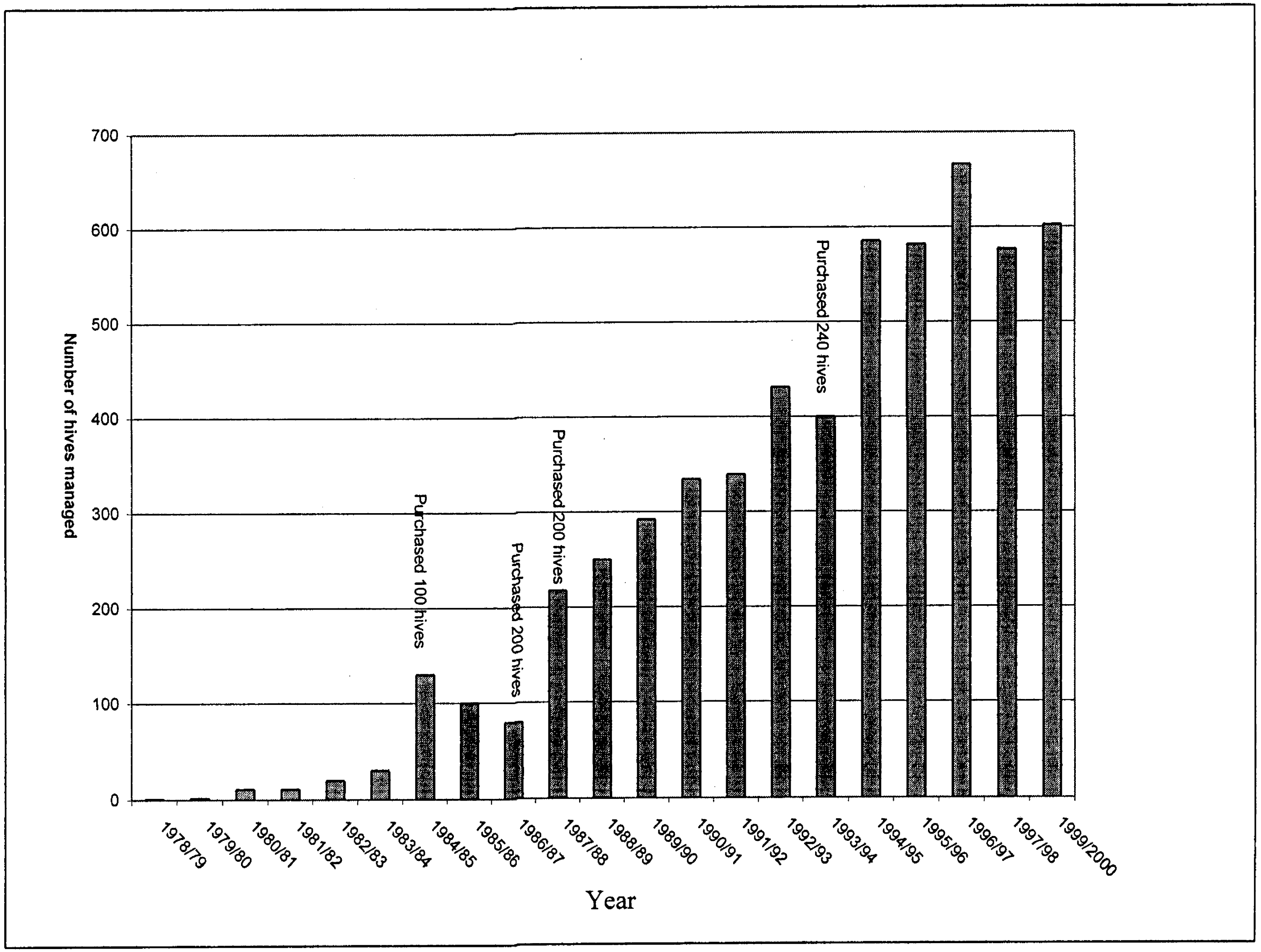


Figure 2.1 The progression in numbers of hives managed for honey production from 1978 to 2000 by Bilga Honey Supplies.

Significant losses occurred each year with an average 15% of the colonies dying during the winter and early spring period. From 1987 to 1988, 60 colonies died, representing 22% of the hives managed. Not all hives were repopulated each spring as the spare boxes created as a result of the colony deaths could be utilised as honey supers or the material may not be in a suitable condition to warrant its continued use in the field.

The losses could be due to a number of factors and vary from year to year:

- A colony may consume all the stored honey over a period of no fresh nectar availability and starve to death.
- A colony may not have access to stored or fresh pollen and continue breeding due to a light nectar flow, eventually running out of protein and die.
- Various diseases affecting adults or the brood may be sufficiently serious to cause the death of the colony.
- The queen may die or its store of sperm may be depleted. If the colony does not take measures to replace the failing or dead queen, then again the colony will perish.

The number of kilograms produced per hive is a function of the ability of beekeepers to find suitable flowering events and manage colonies to maximise populations. However, ultimately, climatic conditions will have a significant influence on the abundance of flowering plants and their capacity to yield nectar and pollen.

Figure 2.2 indicates the volume of honey extracted from each hive from 1986 to 2000. The average over the 15 year period was 97kg/hive. Four years, 1987, 1989, 1994 and 1997 were well below this average. These low years equate to periods of drought influencing the floral abundance and yield capacity of the flora. During the 1987, 1989 and 1994 periods the honey volume obtained from *Echium plantagineum* (Paterson's curse) was exceptionally low compared to other years, indicating drought conditions before and during the spring periods. The 1997 records indicate a poor yield for *Echium plantagineum* followed by no honey obtained over the summer period as a result of an extended drought influence from early spring through until autumn.

Over time each beekeeper will become more knowledgeable in relation to the extent and variation of the floral resources on offer that can be of benefit to the management of their beekeeping enterprise. This knowledge will benefit in two ways; hives can be managed to maximise populations prior to expected nectar flows, and secondly the number of floral species worked by honey bees can be increased through the strategic transportation of loads of hives to take advantage of standing nectar crops. This increasing awareness is illustrated in Figure 2.2 when comparing the two periods from 1986 to 1992 and 1993 to 2000, excluding the four identified drought years. The average honey crop extracted per hive in the first period was 102 kg/hive whereas this rose to 119 kg/hive in the later period.

Des Cannon indicated that the greatest improvement in his ability to make decisions that would benefit his beekeeping operation occurred when he obtained sole use of a vehicle in 1998 and was not reliant on the 'family' vehicle. His ability to scout for suitable sites, and more frequently monitor the potential of the various floral species for future nectar and pollen production gave him advanced notice of when to prepare a colony for future flowering events. This increased the proficiency of the decision making process and resulted in more floral species being considered as potential nectar and pollen sources.

Data on the total number of drums of honey produced per year for Bilga Honey Supplies from 1986 to 2000 is provided in Figure 2.3. This information has been included to indicate to the reader the resultant productivity derived from managing a greater number of hives. This information doesn't necessarily help us understand the prime purpose of this study. However, what it does explain or illustrate is the need for an individual to own a certain number of hives to create a reasonable income. An individual can only manage a defined quantity of hives due to skill and time constraints, in this case Des Cannon managed approximately 600 hives. The economics or profitability of his enterprise can be accurately estimated given production and capital costs which would allow the impact of losing access to a group of floral species to be calculated.

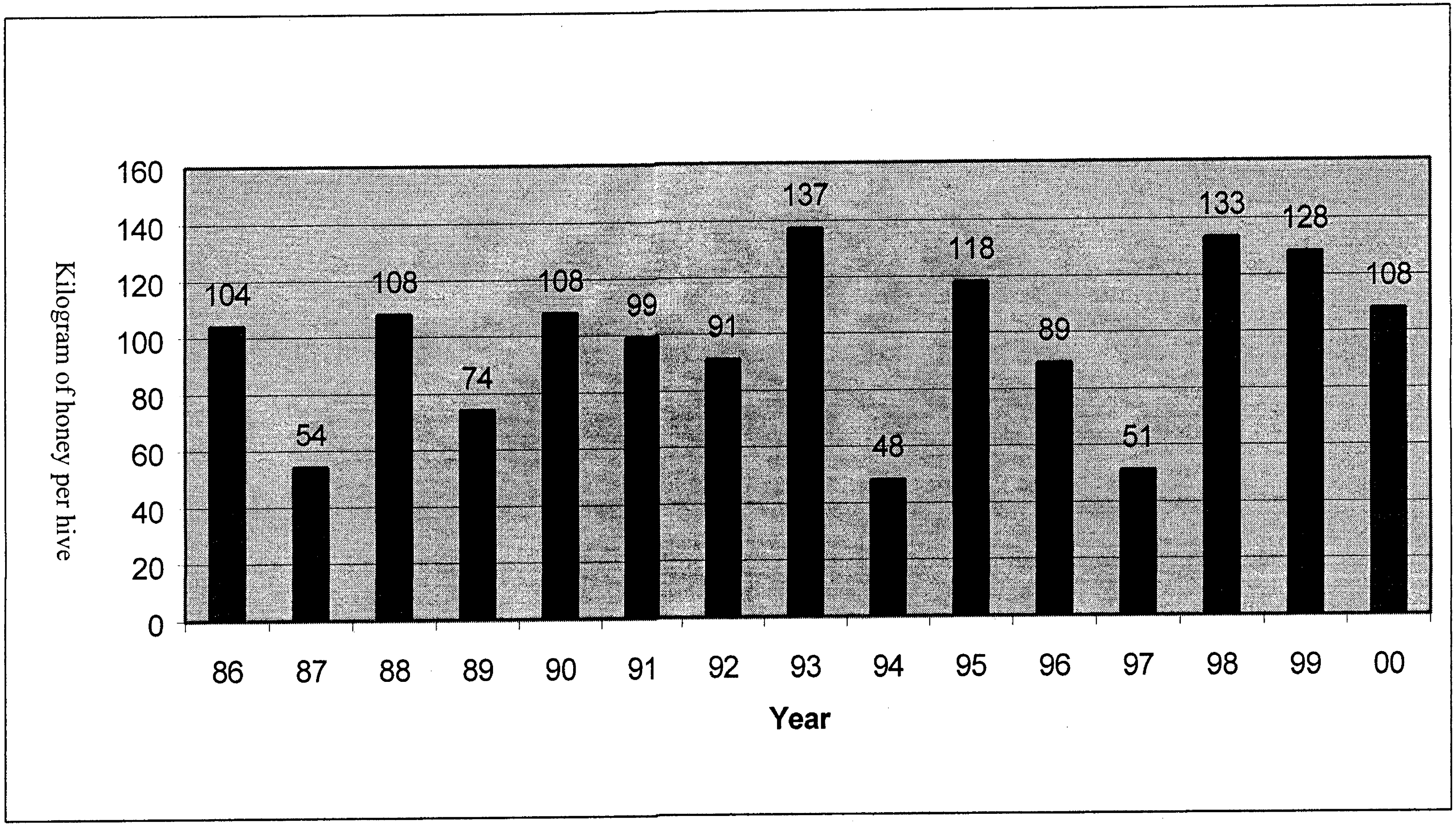


Figure 2.2 Honey production per hive for Bilga Honey Supplies from 1986 to 2000.

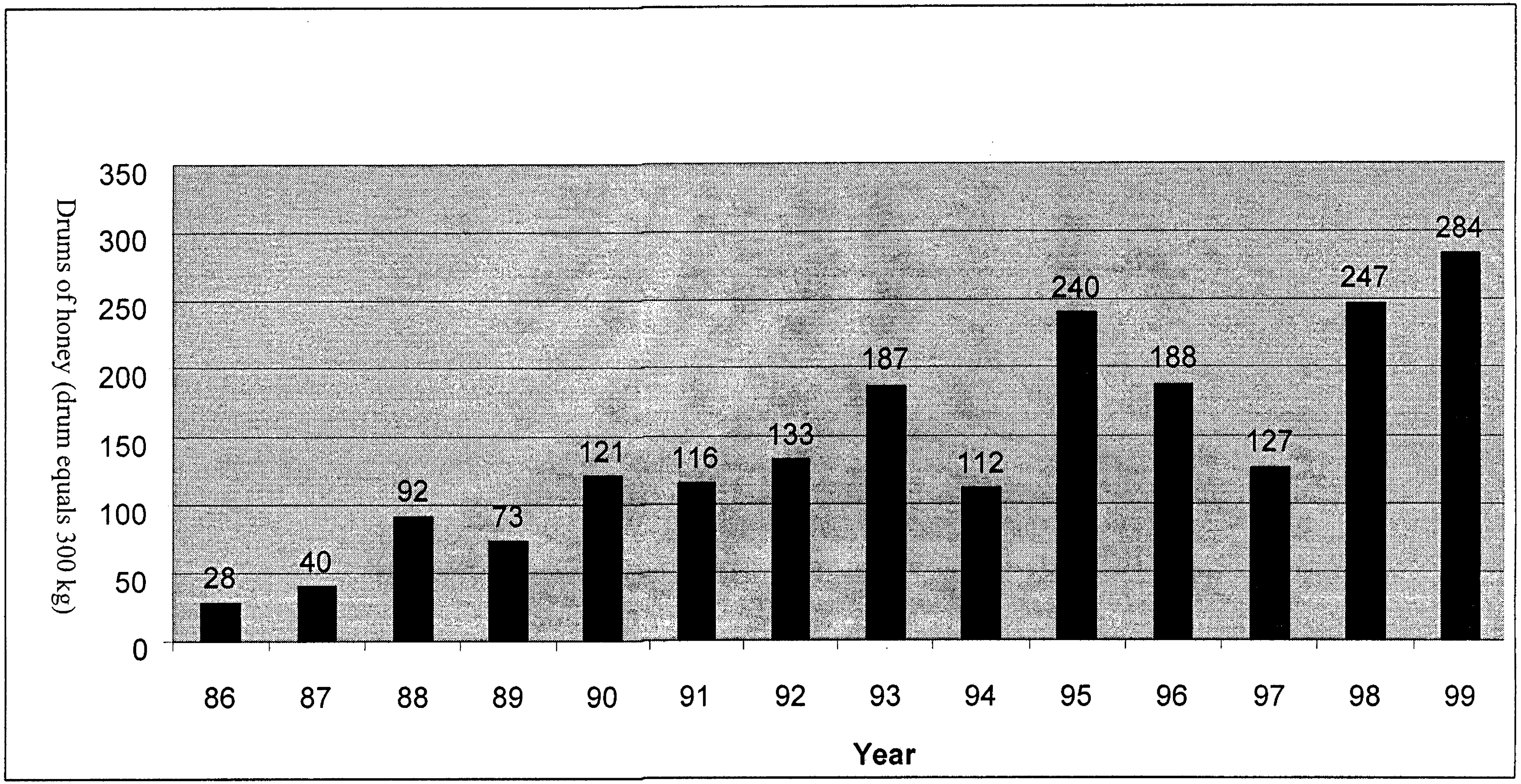


Figure 2.3 Total number of drums of honey produced per year for Bilga Honey Supplies from 1986 to 1999 (Drum equals approximately 300 kg of honey).

The primary floral species targeted by Bilga Honey Supplies are listed in Table 2.1 with the number of drums of honey harvested each year for the individual species. There are some interesting features of this data that should be noted. *Brassica napus* (Canola), *Echium plantagineum* (Paterson's curse) and *Onopordum acanthium* (Scotch thistle) are sourced for honey virtually every year. Due to the early spring flowering period, *Brassica napus* would be of major value also as a source of pollen to provide nutrients to increase the populations of each colony. The honey production associated with *Echium plantagineum* will be directly influenced by the population increase in the colonies as a result of prior access to *Brassica napus* pollen and nectar. Of the 22 floral species stated as major or significant sources of honey, 15 (68%) are eucalypts or related species. Of the remaining species, one is a native shrub or small tree, two are beneficial agricultural species and four are considered by the general agricultural community as weeds.

Even though the eucalypts were the major group of plants targeted for honey production, individual species were not worked annually due to their irregular flowering patterns with two, three or more years between flowering events. This creates considerable complexities in relation to forward planning for the beekeeper in relation to management of colonies to maximise production.

Table 2.1 Primary floral species targeted by Bilga Honey Supplies for honey production from 1986 to 2001.

(Units are drums of honey, 300 kilograms)

Floral source	Month	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01
Brassica napus	Sep.	3	4	6	5	10	16	15	6	11	17	23	10	22	20	21
Echium plantagineum	Oct./Nov.	6	10	50	18	37	54	50	26		147	47	43	111	91	51
Onopordum acanthium	Dec./Jan.	6.5	9	13	8	5	12	20	16		33	15			4	6
Eucalyptus pauciflora	Dec./Jan.	12.5	2.5		2	10	20			39				37		
Medicago sativa	Dec.-Feb.		9	3												
Eucalyptus melliodora	Oct.-Feb.				7	11		27		3					132	41
*Carduus nutans***	Jan./Feb.															
Echium vulgare	Dec.-Feb.						12	8		11				24		3.4
Eucalyptus muelleriana	L.Jan./Feb.			13						18	14					
E. piperita	L.Jan./Feb.			7					14	4						
E. saligna	L.Jan./Feb.			*					*			4				
E. bridgesiana	Feb./Mar.				33				64		29	8			18	8
E. macrorhyncha	Feb./Mar.					25	2						53			123
*E. fibrosa***	Feb./Mar.															
Cormbia gummifera	Mar./Apr.		5.5			1						8				
C. maculata	May-Sep.					22			61	26		10	21			29.4
E. sideroxylon	May-Sep.							13				5		53	15	6.8
Banksia ericifolia	May-Sep.											6				
E. beyeri	May-Sep.											4				
E. dealbata	Sep.											9				
E. blakelyi	Nov./Dec.											21			4	
E. signatta	Feb.-Apr											28				

* *Eucalyptus piperita* and *E. saligna* flower at the same time. Unable to differentiate nectar source.

** Floral sources used for breeding bees or as a drought feeding source - no extracted honey crop recorded against floral species

The single most important species was *Echium plantagineum*. The total contribution of agricultural weeds for the 15 year period varied from 10% in 1994/95 when no *E. plantagineum* honey was produced to 1995/96 when 61% of the total honey crop for this period was *E. plantagineum*. The sporadic nature of the honey produced from eucalypt and related species illustrates the variability of the flowering cycle of this group of plants. *Eucalyptus pauciflora* was the only species listed producing honey for half the years recorded.

The seasonal variability in honey production over the 15 year period is illustrated in Figure 2.4. The main season for honey production was in the spring quarter, the summer and autumn periods produced significantly less quantities of honey. The winter period was restricted not only by available flowering events, but also by the prevailing cooler weather conditions which restricted flight and the time available during the day to forage.

In Figure 2.4 the numbers on top of the bar for each calendar period represent the number of years the main floral sources in the data provided are accessed for honey production out of 10, indicating the regularity and reliability of species accessed for a nectar flow each year. Table 2.2 lists these primary floral species associated with the September, October–November and December–February periods which were more regular than the flowering frequency of autumn and winter species.

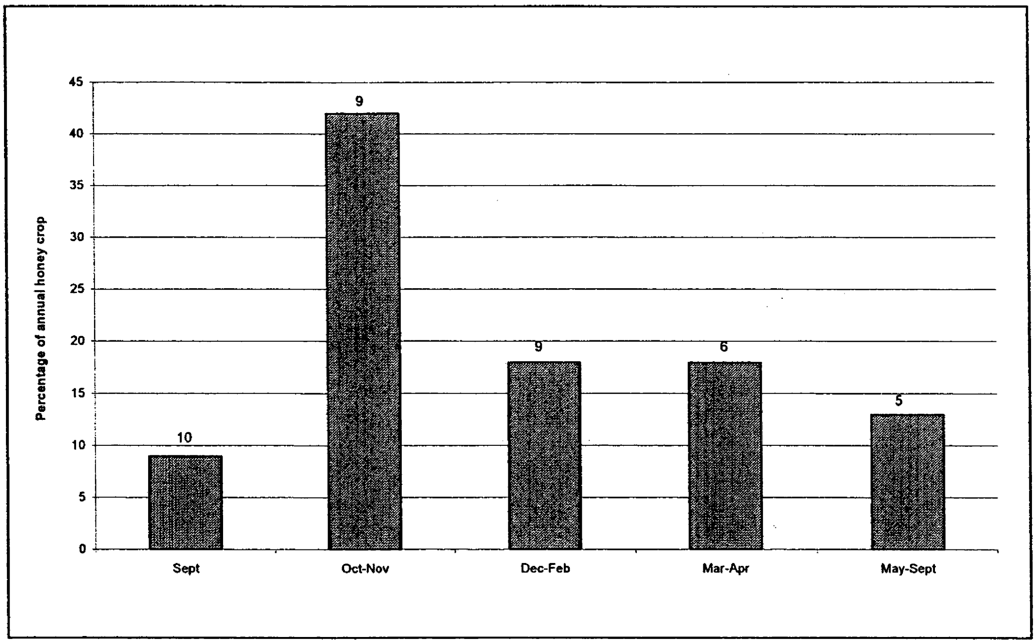


Figure 2.4 Percentage of honey produced seasonally by Bilga Honey Supplies

Table 2.2 The primary floral species of importance seasonally contributing to the total annual honey crop obtained by Bilga Honey Supplies.

Period	Annual %	Years available	Main floral source
Sep	9	10 of 10	*Brassica napus*
Oct-Nov	42	9 of 10	*Echium plantagineum*
Dec-Feb	18	9 of 10	*Onopordum acanthium*, *Eucalyptus pauciflora*
Mar-Apr	18	6 of 10	*E. macrorhyncha, E. bridgesiana*
May-Sep	13	5 of 10	*Corymbia maculata, Banksia ericifolia*

In discussion with Des Cannon, he indicated that he had taken a few years to develop a knowledge of the various floral species that flower on a periodic basis in the autumn which were of value to honey bees. The lack of availability of suitable sites for autumn and winter floral species was identified by Des Cannon as a major limitation in his operational management choices for this time of year. The species mix was therefore not set. It was influenced by two factors, new sites being obtained on floral species not fully utilised by all hives under management, or new species not considered in past years due to insufficient knowledge of the nectar and pollen yield capacity of these species.

The honey production data, particularly for eucalypts, did not necessarily indicate every flowering event for each species listed in Table 2.1. A priority rating will apply to any decision to work a floral source. Factors such as closeness to home, nutritional condition of the colonies i.e., if they need building up in population, the reliability of the floral resource to yield quantities of nectar and or pollen, and the number of suitable sites for each floral species would be considered.

The data provided indicated Des Cannon's preference to work certain species, with a bias to annuals such as *Brassica napus* and *Echium plantagineum*, which are heavily utilised by beekeepers in southern NSW. There is a strong utilisation of *Onopordum acanthium* and *Eucalyptus pauciflora* by Des Cannon, neither of which are sought after as a nectar source by many other beekeepers working the same geographic regions on the same time frame over which these records were kept.

The decision making process by Des Cannon was similar to most commercial beekeeping operators within NSW. That is, to manage honey bee colonies to maximise populations prior to significant predicted nectar flows. These predictions are made from an extensive knowledge about the reliability of the flowering event and the likelihood of yielding surplus nectar and pollen. The data provided in this case study illustrates the spatial and temporal variability of flora as it relates to one singular commercial beekeeping business in southern NSW and is not necessarily typical of all commercial beekeeping operations in southern NSW. The following chapters provide data on the accumulation of knowledge of the regularity, reliability and rewards yielded by floral species identified by commercial beekeepers operating in NSW, similar to that provided by Des Cannon, thus documenting the value of these floral species on a statewide basis.

In discussions with Des Cannon and other NSW commercial beekeepers, for one to succeed at commercial beekeeping, one should be a mechanic, to repair the truck when break downs occur in the middle of nowhere at night with a load of hives; possess good personal communication skills to maintain a network of sites on private property; be familiar with aspects of botany to be able to identify the various floral species; and also an ecologist in order to understand how various events will impact on the local flora to grow, flower and yield nectar. A good business sense is required to enable the management of finances with an irregular cash flow. Planning well ahead, up to two years for some species, will allow equipment and hives to be prepared to make the best advantage of flowering events when they occur. Above all, apart from having a knowledge and understanding of the management of honey bees a commercial beekeeper needs to be an optimist!

CHAPTER 3

REVIEW OF THE COMPLEXITY OF FACTORS AFFECTING CHOICE OF FLORAL RESOURCE BY THE BEEKEEPING INDUSTRY

The information on the spatial, temporal and nutritional variability of floral resources of value to apiculture in Australia is limited. This chapter reviews published research and observations on these subjects which will be built upon in the following chapters. Each aspect of the floral resources utilised by beekeepers and subsequent management implications will be dealt with separately, where possible, to aid in clarity. Although, it has been said that the beekeeping industry is as complex as that part of the natural ecosystem they utilise (Manning 1992).

Factors affecting nectar production

The basis of the New South Wales (NSW) beekeeping industry is honey production, thus nectar secretion characteristics by individual floral species will be of major importance in relation to their value to beekeepers. The volume of honey produced is a factor of the honey bee population and foraging ability of each colony, combined with the availability of nectar secreted from the nectaries of flowering plants. The volume of nectar available will vary considerably from year to year, location to location, season to season, and species to species. To complicate matters, a plant which produces copious quantities of nectar in one location may fail to do so in another (Sawyer 1988).

The factors affecting nectar secretion and the sugar concentration of that nectar are many and will have varying degrees of influence from species to species. The same climatic and soil fertility conditions may promote nectar secretion in one species and suppress nectar secretion in another. The influence of hereditary factors on nectar secretion could be quite considerable. Substantial differences among varieties or clones of plants within a species have been reported for *Trifolium pratense* (Shuel 1986), *T. repens* (Shuel 1986; Jakobsen and Kristjansson 1994), *Medicago sativa* (Shuel 1986; Morthorpe *et al.* 1989) and *Brassica napus* (Szabo 1982; Mohr and Jay 1990;

Kevan *et al.* 1991). A study of three Australian plant species—*Dampiera stricta, Goodenia bellidifolia* and *Aotus ericoides* suggested that nectarvores were likely to encounter a wide range of variability in nectar rewards regardless of which plant species they utilised for nectar (Zimmerman *et al.* 1987).

Nectar secretion varies considerably due to the time of day, probably relating to either temperature gradation or light radiation. Jakobsen and Kristjansson (1994) found that the optimum day temperature for nectar secretion was higher when *Trifolium repens* plants were exposed to low night temperatures, presumably a result of decreased night respiration. Different plant species within the same genus may have quite different environmental requirements for nectar production. For example, *Eucalyptus melliodora* yields nectar best when there are hot nights and still conditions, while *E. albens* requires frosty nights. Some *Eucalyptus* species yield nectar best during showery weather, while other *Eucalyptus* species cease producing nectar when rain occurs on the blossom (Clemson 1985).

Corbet and Delfosse (1984) found that nectar sugars were more concentrated in *Echium plantagineum* the drier the air, a similar pattern for *Echium vulgare* was found in England. They also suggested a link between the photosynthesis rate of the plant and nectar secretion. Honey bees, from their observations, only foraged on *Echium plantagineum* when the ambient air temperatures were above 17°C.

Nectar production has been shown to peak and trough throughout a 24 hour period. The nectar flow in *Anghophora hispida* was greater in the morning (Anderson *et al.* 1983). Bond and Brown (1979) showed that *Eucalyptus incrassata* produced nectar predominantly in the early morning, cold temperatures were stated as reducing nectar production in banksias (McFarland 1985). Law (1994) found no correlation between minimum night temperatures and energy standing crops of nectar in *Banksia integrifolia*. There seems no doubt that the primary influence on nectar secretion is related to sufficient sunlight to support a high level of photosynthesis. Long term records of honey yields indicate the importance of clear weather. Nectar yields may be affected by the quantity of solar radiation received in the previous season (Porter 1978; Shuel 1986).

The influence of soil fertility on nectar secretion is likely to be complex. It may be reasonable to expect that increasing nectar volumes would be available the better the fertility of the soil although this would differ between species. Where biomass concentrations have been established for various forests, it has been estimated that about 63% of all individuals of all species occurring in the forest are concentrated in about 9% of the area which relates to higher nutrient levels (Braithwaite *et al.* 1983). Nectar yield in *Fagopyrum esculentum* varied according to the nutrient mineral elements, nitrogen being of overriding importance (Girnik *et al.* 1977). Soil fertility may have an influence on the frequency of flowering, particularly eucalypt species. As many Australian animals consume significant quantities of nectar, high concentrations of nectar-consuming animals may well be associated with higher fertility sites. The same floral species may yield greater quantities of nectar given the same soil moisture and hereditary influence, growing on a soil with greater levels of fertility. However, the effect of soil fertility may have a greater influence on plant growth and flower development than on nectar secretion. A few studies researching nutrient impacts on nectar yields indicate that when potassium is limited, nectar yields are poor. The effects of various mineral elements on growth are interdependent rather than independent, and the same interdependence can be expected for nectar production (Shuel 1986).

Nectar production was most likely limited by water availability. Beekeeping production records have indicated that the higher yielding seasons were slightly wetter than average and followed a season of higher than average precipitation (Shuel 1986). Thus, physical factors as they relate to soil moisture retention and availability would have a major impact on nectar secretion. Sandy soils were reported to support superior nectar yields in *Trifolium repens* in New Zealand, except in dry years when heavier soils were better (Johnson 1946). The superior drainage in sandy soils would be expected to provide better aeration and warmer temperatures, both of which were found to favour nectar yields in *Antirrhinum majus* (Shuel and Shivas 1953).

The most appropriate method of measuring the volume of nectar available from a floral species is debatable. Potential nectar yields are commonly estimated by taking nectar samples from flowers from which insects and other nectarvores have been excluded, usually by the use of cloth or glassine bag. Protected flowers will secrete nectar for longer periods of time, greater than flowers that have been pollinated. Barbier (1963) reported that flowers of *Lavandula* species quickly wilt and cease to secrete nectar shortly after they have been visited by honey bees. From this it can be assumed that the flower and nectar reward have fulfilled their function, attracting a pollination agent to effect the transfer of pollen and thus the flower no longer has a requirement to secrete nectar. Thus the possibility of a large over-estimate of honey potential is introduced. The nutrients contained in the nectar may be better served nurturing the developing seeds.

Sampling from unprotected flowers would lead to an under-estimation of the nectar potential of a species, making it difficult to utilise such information to estimate the potential honey crops available from a given area. The research presented in this thesis may have considerable merit as a method of valuing various species for their nectar yields determined by measuring the honey produced by honey bees from the different floral species. Also the factors that favour nectar secretion by individual species are well understood by experienced beekeepers providing a very reliable source of antidotal information on this aspect of floral phenology.

The importance of nectar to Australian fauna

Over one hundred species of Australian birds visit the flowers of plants (Ford *et al.* 1979). One of the most abundant and diverse families of Australian birds are the honey eaters *(Meliphagidae)* (Collins 1980), with some 75 species including the chats, probably all of which to a greater or lesser extent feed on nectar (Pyke 1980).

Pyke (1985) hypothesises that the density of resident nectarivorous birds is determined by their ability to obtain energy in nearby habitats. Pyke (1983) also suggests that the density of nectarivorous birds might be more closely related to availability of insects rather than nectar. Even so, many honey eaters are known to be nomadic, i.e., demonstrating a non-repetitive, or only partly repetitive form of seasonal movement which is distinct from migratory behaviour, whereby a bird arrives in and departs from an area at the same time each year (Keast 1968). Traditionally, the Australian commercial beekeeping industry is referred to as migratory when, in fact, it would be more appropriate to refer to beekeeper movements of hives as nomadic.

Population shifts of honey eaters have been shown to occur as birds follow the flowering of plants (Keast 1968; Collins 1980). Keast (1968) indicated that the erratic nature of many movements of Australian honey eaters is mostly accounted for by the irregular blossoming, varying nectar flows from year to year, and by the major nectar-bearing trees flowering at different times in different locations. Flying foxes *(Pteropus poliocephalus)* also exhibit similar patterns of nomadism in their movement onto major flowering events (Eby 1991, 1995). Goldingay (1990) only observed flying foxes on *Corymbia maculata* when at least moderate numbers of flowering trees were present, giving the impression that colonies of these animals will only move onto significant flowering events and avoid low flowering intensities of desirable nectar yielding species. An intensive study of the physiology and biochemistry of nectarivorous bats (Howell 1974) has shown that the pollen of bat adapted flowers is higher in protein than that of closely related flowers pollinated by other means, and that nectar-feeding bats receive the necessary nitrogenous fraction of their diet from this pollen source.

There are many Australian non-flying mammal species which visit flowers (Turner 1982), although their dependence on nectar and pollen has only been studied for a few species. Examples of such species include; Yellow-bellied gliders *(Petaurus australis)* (Goldingay 1990) and Honey possums *(Tarsipes rostratus)* (Hopper and Burbridge 1982). Nectar was utilised whenever flowering trees were present, the only time other food items featured predominantly in their diets was during the absence of blossom (Goldingay 1990).

Many insect species visit the blossom of Australian flora. The native bee fauna consists of approximately 3000 species. They are exclusively anthophilous (i.e., flower frequenting) and constitute the most important group of invertebrate pollinators in Australia. Other important anthophilous invertebrates include beetles (Cantharophily), flies (Myophily), Hymenopterans which include sawflies (Symphyta), bees, wasps and ants (Apocrita), and Lepidopterans which include butterflies (Psychophily) and moths (Phalaenophily) (Armstrong 1979).

Thus the study of nectar production of individual floral species should not be restricted to the benefits derived by honey bees. Studies of nectar yields and flowering phenology, utilising data gathered from beekeepers would benefit our understanding of other nectar feeding species by identifying floral species with a high propensity to provide a reliable food source.

Flowering phenology of melliferous flora

When important melliferous flora is in blossom at the same time every year, commercial apiarists would be expected to move apiaries on a calendar prescription. Unfortunately this is not the case on mainland Australia where much randomness characterises commercial apiary movements. This is because:

i) Flowering in a particular species may not be annual, especially in eucalypts.
ii) The nectar flow varies greatly from year to year in an area, due to both environmental and physiological factors.
iii) A species that has widespread distribution may have a regular flowering season in one part of its range but flower at a different time in another.
iv) Occasionally the melliferous flora in an area may have a phenomenally heavy nectar flow.

Thus commercial beekeepers must retain a considerable elasticity in their decision making as to where to seek nectar flows. The same parameters also characterise blossom seeking bird and blossom bat species (Keast 1968). Flowering frequency and flowering times are major factors in determining the value of various species as a nectar or pollen source for commercially managed honey bees. The stimulus for each event will be a combination of hereditability of the individual species, temperature, available moisture, sunlight intensity and soil fertility.

Essentially a plant must undergo vegetative growth before budding and flowering will be initiated. The group of factors impacting on growth would be the same as those impacting on flowering frequency. Herbaceous plants are expected to have a regular annual growth and flowering event, whereas Australian tree species have been recorded to have a longer flowering cycle. Flowering of eucalypts can be very erratic in regards to the number of years between significant flowering events, although reported examples of this variation are few (Law *et al.* 2000).

Inherent flowering pattern: Inherent differences in response to environment dictate that not all the same species will bloom on exactly the same date when grown at the same location (Caprio 1966). Eldridge *et al.* (1993) reported that the time of flowering in eucalypts was strongly inherited. Within any population of eucalypts the main flowering period for individual trees may be quite out of phase. Such situations have been observed for *Eucalyptus deglupta, E. regnans* and *E. pilularis*. It has been observed that on average *E. regnans* trees flower for 43 days and the order in which individual trees flowered was consistent from one year to the next.

Published lists of flowering times (Costermans 1983; Boland *et al.* 1984; Brooker and Kleinig 1990 a,b) provide only a rough guide as flowering in natural forests will vary widely with site, with provenance, from tree to tree within species and from year to year. Provenance variation in flowering season has been observed in trials of several eucalypt species (Eldridge *et al.* 1993). A trial of *E. camaldulensis* in Zimbabwe (Mullin and Pswarayi 1990) found distinct differences between groups of provenances in flowering season and duration.

Tree age and flowering frequency: The age at which a tree first flowers varies. Cultivated trees of E. *leucoxylon* will flower as early as two years. *E. grandis* may have its first general flowering at two to three years. Some species from cooler climates, *E. diversicolor, E. globulus, E. nitens* and *E. regnans* do not flower heavily, even at wide spacing, until about seven to ten years. *E. dunnii* is perhaps the slowest to start flowering with only a few trees in flower at ten years (Eldridge *et al.* 1993).

The age of a tree may have a bearing on the frequency and intensity of flowering. There are examples of individual eucalypts, having a maximum age of around 1000 years e.g., *E. marginata* and *E. camaldulensis,* (Jacobs 1955). Kavanagh (1987) found that *Petaurus australis* (Yellow-bellied gliders) selected trees with the greatest number of flowers in which to forage for nectar. These would have been the older trees as mature trees (approximately 200 years old) produced 2.2–15.5 times as many flowers as pole stage trees (approximately 25 years old). Ziegler (1993) reported that in mature rainforest in Tasmania, *Eucryphia moorei* (Leatherwood trees) less than 75 years old did not flower. Trees ranging between 75 to 110 years tended to flower sparsely or moderately. Several trees did not flower in consecutive seasons in this age group. The Leatherwood trees that flowered profusely for an extended time (upwards of six weeks) every year ranged in age from 102 to 237 years, although the majority were between 175 to 210 years. Older dominant Leatherwood trees tended to carry a greater volume of flowers over a longer period of time than did young trees. In this case there was no evidence that the quantity of nectar correlates with the age of the tree.

Flower bud initiation: According to Boomsma (1981) the initiation and development of flower buds is said to be primarily controlled by external factors which produce an internal stimulus. In temperate areas the main external factors comprise the length of day and night, and the average daily temperature. In arid areas, many species flower after soaking rains, thus moisture availability is a factor associated with the initiation of flower buds. Not all individual trees of a given species in their native habitat flower together, 50 percent of a single species may not develop flowers in a particular season.

One of the few studies of the flowering phenology of eucalypt species was conducted over a 10 year period at 23 sites observing 20 Myrtaceous tree species (Law *et al.* 2000). They studied the relationship between flowering phenology, climatic factors, environmental and disturbance variables. A number of interesting observations were made during the course of the research. The same climatic factors induced different phenological responses for different species. An 18 month extreme drought led to poor flowering in *Corymbia variegata, Eucalyptus acmenoides, E. grandis, E. resinifera* and *Lophostemon confertus*, whereas the remaining 15 species continued to bud and flower. Surprisingly, across all species combined, the poorest period of flowering was coincident with the years of highest rainfall. This may indicate that rainfall in previous years has a larger influence on flowering than the year in which flowering occurs in eucalypt species.

A very important finding of the research of Law *et al.* (2000), which supports beekeeper observations, is that larger trees, in this case *Corymbia variegata*, flowered more frequently than medium sized trees (large: every 2.3 years; medium: every 5.9 years). There was also a trend in this direction for *E. pilularis, E. tereticornis, E. grandis, E. saligna* and *E. propinqua*. Most species of eucalypts are not thought to seed well, and therefore rarely flower well until they are at least 20–30 years old (Cremer *et al.* 1978). Mature forests of *E. regnans* produced 4.5 times as many flowers per tree than regrowth trees (Ashton 1975). Increasing flower numbers per tree on *C. gummifera* on the South Coast of NSW was positively correlated with increasing tree diameter (Goldingay 1990).

The factors which elicit the flowering response in any one species are presumably day length and temperature, or probably a combination of both (Beardsell *et al.* 1993).

Flower induction in *E. lansdowneana* was influenced by the timing and duration of low temperatures, solar radiation and plant age (Moncur 1992).

Altitude had a significant influence on bud initiation and flowering times of a Tallowwood-Blue gum forest type. Flowering and seed fall of similar species at elevations of 250m-365m preceded flowering and seed fall at elevations of 550m-365m by one to two months, while at elevations of 850m-900m the flowering and seed fall again was preceded by a similar period (Van Loon 1966).

Frequency of flowering events: Beekeeping literature frequently refers to eucalypt species flowering on a two, three or four year cycle (Goodacre 1947; Clemson 1985). Law *et al.* (2000) indicated that on one site three melliferous species, *Angophora floribunda, E. acmenoides* and *E. saligna* failed to flower for a 10 year period, even though these species flowered on other sites during the same time period. In the same study, annual flower abundance was found to correlate with previous seasonal conditions. Prolific flowering followed a wet spring for *C. gummifera, E. pilularis* and *E. robusta*. The reverse was found for *E. grandis, E. siderophloia* and *Lophostemon confertus* which flowered profusely after a dry spring. Flower abundance for *E. propinqua* correlated with a previously dry winter and summer. These observations support the theory that each species behaves differently in relation to floral phenology in response to various climatic variables. The concept of a regular two, three or four year flowering cycle is not supported, rather a combination of factors need to be met. Normally a rest period is required, followed by the right combination of climatic events to suit each individual species before bud initiation occurs, followed by flowering. It is apparent that each floral species is potentially unique, in relation to bud initiation and flowering, with some degree of similarity with other floral species. Observations by experienced beekeepers over many years provide an exceptional pool of knowledge as to what triggers are important for individual melliferous species and the flowering behaviour of various species in each geographic region.

Distribution of melliferous flora

The distribution of any particular floral species will be dependent on climatic factors including minimum and maximum temperatures, frost occurrence, humidity, cloud cover or solar radiation, rainfall, soil water availability and physical factors including soil structure and soil fertility (Boland *et al.* 1984). Each species will have its own set of parameters which will impact on its geographic distribution. Some species will have a very defined set of criteria within which they can grow, whereas other species will have a broader set of criteria which allows the species to have a wider geographic distribution. Species in both categories are likely to be beneficial melliferous species, although not necessarily across their entire growing range.

General descriptions of the distribution of indigenous flowering trees (Boland *et al.* 1984), particularly eucalypts (Brooker and Kleinig 1990 a,b) and indigenous shrubs (Costermans 1983) can be found in a number of general publications (Harden 2002). Clemson (1985) has published the distribution of the major NSW melliferous floral resources for beekeepers, although the distribution information has probably been gleaned from other authoritative publications on flora.

Beekeeper surveys: Goodacre (1947) indicated that he attempted to survey beekeepers over a number of years but found the exercise unsuccessful. More recently, Cocks and Dennis (1978) conducted a survey of beekeepers in a defined area of the South Coast of NSW. This survey was well supported and thus the information gathered represented many individual observations documenting the range of species, flowering patterns and nectar and pollen values of the various species. This study also included distribution of each species. Similarly designed and targeted surveys would be expected to yield similar information, thus providing a truer picture of the distribution of melliferous species, rather than adopting the general distribution of a species as having similar values for pollen production, nectar yields and the regularity and reliability of flowering patterns throughout its range.

Colony size and climatic constraints on foraging behaviour

Constraints other than the availability of floral resources and nectar availability on the foraging behaviour of a colony of honey bees, will impact on the quantity of nectar and pollen harvested. The two main constraints are climate and colony size.

Climatic factors have a major influence on a colony and its foraging behaviour. Honey bees have only limited ability to regulate their body temperature and are thus restricted to bands of suitable temperature regimes for flight. Various sources indicate that a band width between 8° and 17°C reduced flight considerably (Corbet and Delfosse 1984; Gary 1986; Crane 1990; Free 1993). Temperatures below 7°C soon induce individual honey bees to become motionless (Gary 1986). Temperatures below 14°C induce a colony to cluster, preserving heat and enabling the colony to survive in cold climates (Gary 1986). Direct radiant heat from the sun has been reported to help bees maintain an adequate body temperature to enable normal flight (Corbet and Delfosse 1984). Thus air temperature does not give a true guide of the potential foraging activity of a colony, for on clear sunny days the radiant heat will assist honey bees in maintaining body temperatures. This aspect of honey bee activity has been observed frequently in orchards in early spring as they tend to forage closer to their hives during cloudy, windy or cool weather (Free 1993).

As a colony increases in size, the number of honey bees surplus to those required to attend larvae and queen requirements are available for foraging activities. The larger this surplus, the greater the colony's ability to forage for pollen and nectar and the greater potential exists for larger honey yields to be harvested per hive. In field trials, Kleinschmidt *et al.* (1974) measured the production of honey from colonies with significant population differences. Colonies averaging 50,000 bees produced 4.2 kg of honey per day, whereas colonies with a population of 35,000 bees produced 2.2 kg per day on a warm weather honey flow. The effect of nutrition on birth and death rate, body crude protein levels and body weight influenced the colony population and honey production.

Honey bee dietary requirements — pollen

Honey bees require a range of elements to satisfy their nutritional requirements for normal growth and development. These elements include proteins (amino acids), carbohydrates, minerals, fats (lipids), vitamins and water. Pollen normally satisfies the dietary requirements for proteins, minerals, fats and vitamins. The proteins are composed of a series of amino acids, ten of which (threonine, valine, methionine, isoleucine, leucine, phenylalanine, histidine, lysine, arginine and tryptophan) have been identified as being essential for honey bee nutritional requirements (deGroot 1953). Glycine, proline and serine were not essential for growth but did exert a stimulating effect at sub-optimal growth levels (deGroot 1953).

Availability of pollen, either stored or freshly gathered, is required for the feeding of larvae and young nurse bees up to the age of 15 to 18 days. The largest amount of pollen is consumed by three to six day old adult honey bees during spring breeding conditions, extending to nine day old honey bees during summer (Zherebkin 1965).

Fresh pollen is still regarded as the most ideal source of nutrition for honey bees compared to stored pollen and artificial pollen supplements. Haydak (1961) demonstrated that fresh pollen was 100% effective in stimulating the development of the hypopharyngeal glands in worker bees, whereas pollen stored at room temperature for one year had decreased its stimulating effect by 76%. Pollen stored for two years failed to initiate brood food gland development.

The quantity of pollen a colony consumes will largely depend on the availability of pollen to foraging honey bees and the demands from the colony in the form of developing larvae and young adult honey bees. Doull (1974) suggested that on average, 125 mg of pollen was consumed for every larvae reared in the colony. A strong colony with upwards of 200,000 honey bees in a year will require at least 25 kg of pollen annually. Doull also suggests this is an under-estimate for it does not take into consideration the pollen consumed by adult honey bees in the production of beeswax. Doull did not include the amount of pollen young adult honey bees consumed from when they hatch until two weeks of age, after which they largely consume only carbohydrate. Thus, a productive colony could have a need for 50 kg of pollen per year. If the production season is long and a commercial beekeeper is regularly moving hives onto nectar flows and breeding conditions for much of the year, then again the amount of pollen required per annum could exceed 50 kg/colony.

Protein: Ample protein promotes a high birth rate and long-lived honey bees, whereas protein deficient conditions minimise the birth levels and length of life of adult honey bees (Kleinschmidt and Kondos 1977). Kleinschmidt and Kondos (1976) concluded that pollens with less than 20% crude protein could not satisfy colony requirements for optimum production. They indicated that for every 10 grams of protein required by the colony for net production, it was necessary for about 48 grams of pollen containing 30% crude protein to be consumed. If the protein content of pollen was reduced from 30% to 20%, the colony would be forced to increase its pollen consumption from 48 grams to 72 grams in an attempt to maintain satisfactory levels of production. They also indicated that a strong colony would require about 55 kg of pollen per year and if the quality of pollen decreased, then a colony would have to increase the consumption of pollen to make up for the reduction in nutrient content of the pollen.

Adequate protein also has a major role in the rearing of drone bees. Nguyen (1999) found that drones with higher body protein levels reached sexual maturity earlier than those with lower body protein levels, and that drones fed adequate protein produced higher numbers of spermatozoa than those fed low protein diets. This has significant ramifications for the rearing and supply of mated queen bees for sale to beekeepers. Drone mother colonies should have access to high quality pollen, or the provision of protein supplements, to ensure dietary deficiencies are not placed on the colonies rearing drones for mating with virgin queens.

Amino acids: Ten amino acids have been demonstrated by deGroot (1953) as being essential for honey bee nutrition (Table 3.1). If a pollen is lacking in one or more of these essential amino acids, then the quantity of pollen consumed would need to be increased to obtain the quantities of the amino acids required. Pollens with low protein levels would expose honey bees to more severe amino acid deficiencies. Low levels of protein and essential amino acid would be more of a problem to a colony when there is reduced quantities of pollen stored in combs around the brood and only low volumes of pollen available in the field. A colony will require less pollen with a high protein content and all the essential amino acids at or above deGroot's recommended minimum levels, than it would if the protein content was lower or deficient in one or more amino acid. Research into aspects of honey bee nutrition in the Australian context have largely focussed on measuring the crude protein and amino acids in honey bee-collected pollen (Rayner and Langridge 1985; Kleinschmidt 1986; Muss 1987; Stace 1996a). These studies have largely taken place in Victoria, Northern NSW and Southern Queensland, thus focussing on species providing pollen to bees in these areas.

Table 3.1 Essential amino acids for satisfactory honey bee nutrition (deGroot 1953).

Essential amino acids	*Bee requirements g/16g N*
Threonine	3.0
Valine	4.0
Methionine	1.5
Isoleucine	4.0
Leucine	4.5
Phenylalanine	1.5
Histidine	1.5
Lysine	3.0
Arginine	3.0
Tryptophan	1.0

Fat/lipids: Fat refers to lipids which include fatty acids, sterols and phospholipids. It is thought that fatty acids are necessary components of the phospholipids which play an important role in the structural integrity and function of cellular membranes of insects (Dadd 1973). Under normal conditions, any lipid requirement is satisfied by the consumption of pollen (Herbert 1992). Research conducted by Herbert and Shimanuki (1981) indicated that the sterols cholesterol or 24-methylenecholesterol supported brood rearing when included with diet supplements, compared to other diet mixes. They concluded that either cholesterol or 24-methylenecholesterol should be the sterols incorporated in dietary studies. However a diet of unsupplemented lactalbumin yeast containing 0.01% indigenous cholesterol, when supplemented with cholesterol (0.1% dry weight) did not increase brood rearing, which lead the researchers to believe that 0.01% level must have satisfied the requirements for brood rearing (Herbert and Shimanuki 1981). The cholesterol requirements for brood rearing could have also been satisfied from body reserves within the attendant nurse honey bees.

Other than the need for cholesterol, the dietary needs of honey bees for fats or lipids is unknown. The role of fats and lipids could be additional to the nutritional requirements of honey bees. There are two other functions that appear to be possible in explaining the role of fats and lipids in pollen. Fats in pollen would appear to act as strong attractants to foraging honey bees and certain fatty acids exhibit significant antimicrobial activity.

Singh *et al.* (1999) found that pollens with high lipid levels were preferred by foraging honey bees over those pollens with lower lipid levels. The addition of either whole pollen lipids or the fraction soluble in cold acetone significantly increased the amount of dietary supplement consumed by caged honey bees. The addition of the fraction insoluble in cold acetone, or of an extract of the volatile substance in pollen, led to decreased food consumption (Nation and Robinson 1968). This indicated that the addition of fat and lipids to artificial diets may be beneficial or detrimental, depending on the composition and quantity of the individual components of the lipids. The role of lipids as phagostimulants (attractants) appears to have merit when examples of pollens with nutrient qualities low in protein but high in fat content are far more attractive to foraging honey bees (Todd and Bretherick 1942; Standifer 1966). Historically, the view has been held that the more attractive pollens have a higher food value for brood rearing, whereas in fact this was not a true indication of the actual nutrient contribution to brood rearing (Todd and Bretherick 1942). Singh and Singh (1996) suggest that *Brassica campestris* (mustard) pollen on its own may have a greater effect on improving brood production than feeding pollen from a mixture of sources not including mustard. The protein levels were average at 21.7%, although the authors regarded this as a "rich protein source", the lipid level of 9.2% was considerably higher than reported lipid levels for other species.

Pollen may have a sanitary role in the colony due to the antagonism of certain fatty acids to two major bacterial honey bee brood diseases. The role of fats/lipids as antimicrobial agents within the hive has been investigated by Feldlaufer *et al.* (1993). It was found a fatty acid compound (linoleic acid) within pollen inhibited the growth of the two bacteria that cause European foulbrood *(Melissococcus pluton)* and American foulbrood *(Paenibacillus larvae* subsp. *larvae)*. A number of other fatty acids including capric, lauric, myristic and linoleic acids are also known to have antimicrobial properties (Feldlaufer *et al.* 1993).

Very few fatty acid compositions of honey bee collected pollen have been analysed to determine the levels of these antimicrobial components. Manning (2000) reported on the fatty acid composition of six eucalypt species originating from Western Australia, finding significant differences in the linoleic acid and linolenic acid levels. The implications for honey bee disease management within apiaries has not been established and offers some excellent avenues for research.

The total fat/lipid content of corbiculum pollen has been reported by Todd and Bretherick (1942); Youssef *et al.* (1978); Day *et al.* (1990); Singh *et al.* (1999) and Manning (2000). Todd and Bretherick (1942) analysed 34 pollen samples using ether extract and found a wide range of values from 0.94 to 14.44% with a mean of 4.96%. The highest values were for *Brassica campestris, B. kaber* and *B. nigra*, and *Taraxacum vulgare* [syn. officinale] which beekeepers considered as outstanding sources of pollen on which to breed bees. Youssef *et al.* (1978) analysed pollen collected from four species with lipid contents expressed as a percentage of dry weight for *Vicia faba* 12.53%, *Brassica kaber* 10.25%, *Zea mays* 9.31%, and *Trifolium alexandrium* 8.36%. Day *et al.* (1990) discussed the composition of pollens collected from seven species including pollen from both male and female *Actinidia deliciosa* (Kiwifruit blossom). The fat content was expressed as a percentage of dry matter for *Hieracium pilosela* 13.4%, *Trifolium repens* 8.17%, *Salix* spp. 5.04%, *Rubus fruticosus* 2.25%, *Cytisus* spp. 2.07%, *Discaria toumatou* 1.24% and *Actinidia deliciosa* male 0.17%, female 1.1%.

Singh *et al.* (1999) reported on the total lipid content of six species (% of dry pollen mass): *Brassica campestris* 20%, *Raphanus sativus* 17.3%, *Brassica juncea* 14.5%, *Psidium quaua* [syn. guajava] 13.4%, *Allium cepa* 13.2%, and *Petunia hybrida* 8%. Manning (2000) reported very low levels of lipid contents for six eucalypt species ranging from 0.59% for *Eucalyptus marginata* to 1.9% for *E. diversicolor*.

Further samples of pollen need to be analysed for the fat/lipid levels to be quantified so the range and variation of this dietary component occurring in honey bee collected pollen can be qualified. Given field observations, it is very likely that increasing fat composition of pollens improves the attractiveness of pollen to foraging honey bees. Thus there are implications to the floral species in question, providing them with a pollination advantage. Research is limited on the absolute fat/lipid requirements of honey bees or on the definitive benefits to honey bees of various fatty acids. This area of honey bee nutrition is in need of detailed studies to determine the dietary function of fats/lipids and thus determine their importance.

Minerals: Little is known about the mineral requirements of honey bees (House 1961; Herbert and Shimanuki 1981). Substantial amounts of potassium, phosphate and magnesium are required by all insects (Dadd 1973), although excessive levels of sodium, sodium chloride, and calcium have been shown to be toxic to honey bees (Nation and Robinson 1968; Herbert 1979; Horr 1998).

Various elements can be found in pollen including potassium, magnesium, calcium, sodium, iron, copper, manganese, zinc, aluminium, cadmium, chromium, lead, nickel and selenium, although many elements are only present as trace amounts (Todd and Bretherick 1942; Nation and Robinson 1971; Youssef *et al.* 1978; Day *et al.* 1990; Anderson 1997; Manning 2000). A total of 27 trace elements in pollen and honey bee larvae were reported by Grigoryan *et al.* (1971). Pollen is said to normally contain between 2% and 4% ash on a dry weight basis (Nation and Robinson 1971; Herbert and Shimanuki 1978), or 1% to 7% of minerals (Lunden 1954), although honey bees reared on a synthetic diet containing various concentrations of pollen ash reared the greatest amount of brood at 0.5% to 1% ash levels (Herbert and Shimanuki 1978).

Mineral supplements designed for sheep and cattle have been fed to honey bees, but have shown to be unsatisfactory for adult honey bees (Nation and Robinson 1968; Herbert and Shimanuki 1977). These mixes have been found to be lacking in potassium (House 1961) and contain excessive calcium and sodium (Dadd 1973).

Research determining the ideal levels of major and trace elements needed by honey bees has not been carried out due to difficulties in administering the minute levels required, plus the time and cost involved. Another possible method of determining the levels of minerals required by honey bees is to analyse bee collected pollens to obtain average levels for each element across the same species and between species.

This study

In the context of the literature reviewed in this chapter, the following chapters provide data supplied by commercial beekeepers operating in NSW and chemical analysis of honey bee-collected pollens, building on our understanding of flowering frequencies, flowering range, distribution, nectar and pollen reward capacity of floral species including the nutrient content (protein, amino acids, fats and minerals) of honey bee-collected pollens.

CHAPTER 4

FLORAL RESOURCE DATABASE SURVEY

INTRODUCTION

The purpose of this chapter was to document the floral resources on which the New South Wales (NSW) beekeeping industry was dependent based on direct beekeeper contribution via a comprehensive survey. This survey provided information on the distribution of the various species as they relate to beekeeping interests, the frequency with which these resources were used, the land tenure on which they occur, and the relative values for honey production and pollen as they related to honey bee nutritional requirements.

Access to flowering plants is fundamental to the beekeeping industry. There is only a limited volume of information available regarding the productivity, economic value and geographic significance of the floral resources of NSW in relation to the beekeeping industry. It has been suggested by Bill Winner (pers. com. 1997, Beekeeper Services Manager, Capilano Honey Ltd., Queensland) that around 80% of the Australian honey crop is derived from Australian native species. Somerville and Moncur (1997) indicate that 70% of the NSW honey production was obtained from eucalypt species.

To date, there have only been a few localised studies of beekeeping utilisation of flora. Cocks and Dennis (1978) surveyed 64 beekeepers on the South Coast of NSW listing the plant species of apicultural importance and suggesting that on rough calculations the area studied might be capable of producing $1,200,000 worth of honey per annum. Such studies highlight the previously unknown value attributed to flowering plants capable of yielding nectar that could be harvested by honey bees. Without a comprehensive and detailed study on the value of various floral species across NSW or specific regions, it would be very difficult for the beekeeping industry to adequately and professionally argue the value of various floral species. Thus the need for a survey to address this shortfall of information across the whole State.

As the intention of this chapter was to document the floral resources of NSW as they relate to the beekeeping industry, it was of value to briefly review past publications with a similar theme. Three books have been published on the subject although none clearly prioritise the floral species valued by beekeepers. The authors have drawn on their significant personal experience in their association with the beekeeping industry to compile the information and have not directly obtained information from beekeepers on a broad scale. Goodacre (1947) surveyed beekeepers but obtained a poor response in his attempt to gain a greater depth of beekeepers knowledge on the flowering behaviour and floral rewards of melliferous flora.

Rayment (1934) wrote the book *Profitable Honey Plants of Australasia*, in which much of the information relates to flora in NSW. Rayment states that this handbook is "the first of its kind on Australasian plants that fill the treasury of the bee hive, and render possible the financial success of the modern bee farm". The book includes a list of nectar and pollen producing plants of major and minor importance to beekeeping. Only passing mention of some species of known present value to beekeeping and comments on the value of floral species to beekeeping in other countries, leads one to assume that this publication is far from complete. Rather it was the first attempt in Australia to draw together as much information (known to the author) as possible on the value of various floral species to honey bees.

This was improved on by Goodacre (1947) who wrote the book *The Honey and Pollen Flora of New South Wales*. Goodacre states that "until recent years it seemed sufficient for a beekeeper to make a study of his own locality, since beekeeping was then conducted on permanent sites. With the advance of migratory work however, bees are now moved long distances and a knowledge of the flora of the various parts of the State in which apiculture is carried on has become an important factor in successful operations." This publication deals with flora, district by district, stating the relative honey and pollen values for the various species. Goodacre does state that he "attempted" a survey of beekeepers over a three year period to collect information for his book but "the response was not as good as was anticipated". His publication was a significant improvement on Rayment's (1934) although it lacked detailed information on the flowering regularity of the listed flora and only occasionally mentioned the value of pollen and value of honey harvested by beekeepers.

The third significant and most recent publication detailing honey and pollen flora within

NSW was that by Clemson (1985) who compiled a lifetime of experience and knowledge into a book titled *Honey and Pollen Flora*. Clemson's book briefly covers hive management and migration, difficulties associated with certain nectar flows and includes detail on 298 species of flora of significance due to their honey production and/or pollen values. He also provided more specific information on the flowering cycles of the various species and commented on beekeeping management considerations applicable to honey bees foraging on individual species. This publication was extremely informative in relation to the value of various floral species to honey bees, more so than the previous two authors. Reading the text, it is difficult to quantify a comparative value contributed by each floral species to beekeeping interests within NSW, providing a hierarchy of the most important species.

MATERIALS AND METHODS

A pilot survey was conducted in July 1996 when 20 NSW commercial beekeepers were sent survey forms asking for detailed information on each apiary site utilised in the last 5 years. The beekeepers were asked to identify all floral species of value to honey bees, including information on flowering duration and frequency, honey yields per hive, and a subjective value as a source of pollen with a rating from 1 (least) to 5 (greatest). Further information was also requested in relation to the land tenure of each site and their exact geographic location. A 65% response was achieved from this pilot. As a result of feedback on survey design and the nature of the replies, the survey was modified with more clarity in the questions and a simplification of the location for each site to the nearest town. Location of sites was evidentially very sensitive information held by individuals with few willing to divulge such information for public exhibition due to possible future competition for access to these sites.

Survey forms: were sent to the 425 beekeepers listed on the NSW Agriculture Beekeeping Registration System with 200 hives or more. In the package mailed on April 1997 was a covering letter, survey form and reply paid envelope. A further copy of the same survey form, a covering letter and reply paid envelope was again sent to non-respondents in August 1997. The second survey mailing included a tea bag with a note for the recipient to "sit down, have a cup of tea and take a few moments to consider the following". Individual beekeepers were interviewed at meetings from June 1997 to December 1998 and at the NSW beekeepers' state conference in May 1998. A "last chance" letter to beekeepers was sent in November 1998 with the survey form and reply paid envelope. Copies of the survey form and the three covering letters can be found in Appendix 3.

Data entry: the data was entered into a program designed to operate on Microsoft Access '97 and Excel '97. To increase the security and integrity of the individual beekeeper detail within the NSW beekeeper census database, a password was used. This allowed only individuals with the correct password to access the information in the database. Data entry began in mid-1998 and concluded in February 1999. Data was exported to ArcView GIS for the generation of maps, refer Appendix 5.

For those beekeepers who failed to respond to the survey, estimates were derived for numbers of working hives and apiary sites. This was done using a linear prediction model using number of registered hives as the predictor variable.

Common name: The use of common names in the returned forms for floral species created a major problem in deciphering which species each beekeeper had referred to. Where a beekeeper stated a common name that could be identified with more than one species, the geographic location, values of honey and pollen and flowering period were used, where possible, to list the plant as a specific species. This was not possible in some cases. For example, the name "stringybark" did not allow the entry to be categorically stated with any degree of confidence that a beekeeper was referring to any particular species especially on the Northern Tablelands. Thus, in this case, a separate category was created for "stringybark" and referred to as *Eucalyptus* species, as the term stringybark could relate to any of 25 species of eucalypts in NSW.

Problems that were apparent in identifying the botanical name from the common names given are summarised as follows:

- The one plant may be known by several common names.
- The one common name may refer to several different species.
- Some less known species may not have a readily used common name.
- The same common name may be used for the one group of species.

Major examples in this study include:

- Red gum, which may refer to:

- Blakely's red gum *(E. blakelyi)*
- River red gum *(E. camaldulensis)*
- Hill gum *(E. dealbata)*
- Forest red gum *(E. tereticornis)*

- Grey ironbark may refer to *E. paniculata* or *E. siderophloia.*
- Stringybark may refer to:
  - Red stringybark *(E. macrohyncha)*

    [Red stringybark is a common name given to Red mahogany *(E. resinifera)* on the North Coast]
  - Broad-leaved stringybark *(E.caliginosa)*
  - Yellow stringybark *(E. muelleriana)*

    [Yellow stringybark was a common name given to White mahogany *(E. acmenoides)* on the North Coast of NSW]
  - White stringybark *(E. globoidea)*
  - Silver-topped stringybark *(E. laevopinea)*

    [referred to as clean limb or white limb]
  - Needlebark stringybark *(E. planchoniana)*

    [referred to as Planchon's stringybark]
  - Blue-leaved stringybark *(E. agglomerata)*
  - Thin-leaved stringybark *(E. eugenioides)*
  - Grey stringybark *(E. nigra)*

    [referred to as White stringybark or Queensland stringybark]
  - Narrow-leaved stringybark *(E. oblonga)*

Other species (Brooker and Kleinig 1990a) referred to as stringybarks, not stated in the results, include:

- Bailey's stringybark *(E. baileyana)*
- Brown stringybark *(E. baxteri)*
- Blaxland's stringybark *(E. blaxlandii)*
- Diehard stringybark *(E. cameronii)*
- Capertee stringybark *(E. cannonii)*
- Camfield's stringybark *(E. camfieldii)*
- Brown stringybark *(E. capitellata)*
- Argyle apple or Mealy stringybark *(E. cinerea)*
- Privet-leaved stringybark *(E. ligustrina)*

- McKie's stringybark *(E. mckieana)*
- Messmate stringybark *(E. obliqua)*
- Tindale's stringybark *(E. tindaliae)*
- Youman's stringybark *(E. youmanii)*
- Blackbutt may refer to Blackbutt *(E. pilularis)* [as occurs on the coast] or New England blackbutt *(E. andrewsii)*. New England blackbutt can either be *E. andrewsii* subspecies *andrewsii* or *E. andrewsii* subspecies *campanulata*. Subspecies *andrewsii* may also be referred to as Messmate. Messmate is also the common name for *E. obliqua.*
- Scribbly gum could refer to *E. haemastoma, E. racemosa, E. rossii, E. sclerophylla* or *E. signata.*
- Grey gum could refer to *E. propinqua,* [also referred to as Small-fruited grey gum] *E. punctata* [also referred to as Large-fruited grey gum], *E. biturbinata, E. canaliculata* or *E. major.*
- Spotted gum may refer to *Corymbia maculata* or *C. variegata.*
- Turnip weed was a common weed of farming areas in NSW. Other plants also bear a resemblance, or closely associated common name: Turnip weed *(Rapistrum rugosum),* Wild radish *(Raphanus raphanistrum),* Wild turnip *(Brassica fruticulosa* and *Brassica tournefortii.*
- Scotch thistle was a common name given to a few thistles. *Onopordum acanthium* is a rather large thistle growing 1–2 m high, whereas *Cirsium vulgare* is a much smaller thistle, and is also referred to as Black thistle or Spear thistle.

RESULTS

Response rate to survey: All commercial beekeepers with 200 or more hives were asked to contribute to the survey, thus the project was, in essence, a census of the beekeeping industry. Responses were varied: some beekeepers put incredible detail into their forms, whereas others gave the barest of information. The second mailing had a favourable reaction with a reasonable response. Some beekeepers returned the tea bag used and some sent beer bottle tops and coffee bags, with a note to send coffee next time. A total response of 81% was achieved, as outlined in Table 4.1.

Table 4.1 Percentage response to the beekeeping survey posted to 425 beekeepers with 200 hives or more registered.

Response	Percentage
1st census mailing — April 1997, due June 1997	40
2nd census mailing — 1 August 1997, due 31 August 1997	18
Personal interview — July 1997 to December 1998	12
3rd census mailing — November 1998, due December 1998	11
Failed to respond to census	19

The total of 393 beekeepers was reduced from the 425 beekeepers originally surveyed, due to amalgamation of data from beekeeping operations where more than one registration covered the same beekeeping enterprise, or the number of hives owned by a beekeeper fell below 200 by November 1998 from April 1997, or the beekeeper no longer kept hives. The total number of responses per hives owned and operated is provided in Table 4.2 where it can be seen that the best response was from beekeepers with the highest number of hives and the lowest response was from the group of beekeepers managing the least number of hives.

Table 4.2 Beekeepers responding to survey from each category.

Hives owned	Total no. of beekeepers	No. of beekeepers returning census	% of beekeepers responding to census
200 – 400	230	150	65
401 – 600	73	58	79
601 – 800	39	36	92
801 – 1000	24	18	72
1001 – 1500	18	16	89
1501 – 2000	7	8 *	100
> 2000	2	3 *	100
Total	***393***	***319***	
* numbers of beekeepers increased from the start date of the census.			

Number of production hives: The following graph (Figure 4.1) illustrates the distribution of beekeepers owning more than 200 hives derived from the survey returns. The 200 to 400 hive category was the largest group of beekeepers, although only 65%

of beekeepers responded to the survey in this hive category. The average response for all other categories with more than 400 hives was 96%. One beekeeper is not illustrated in Figure 4.1 as he managed more than 4000 hives.

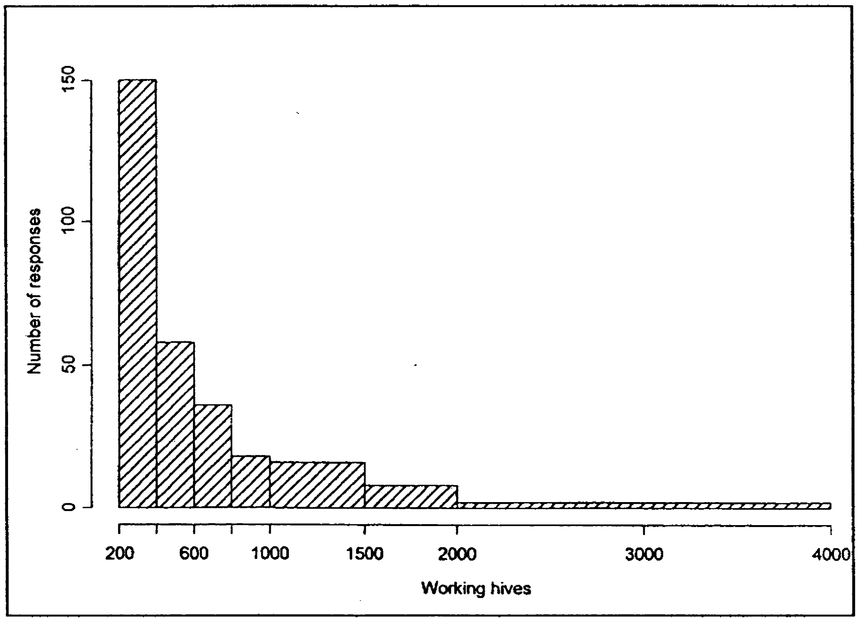


Figure 4.1 The number of responses to survey re number of production hives over the 5 year period 1992 to 1997.

Honey production per hive: The average honey production extracted per hive ranged from 41 kg per hive for beekeepers with less than 200 hives to 111 kg for beekeepers with hive numbers ranging from 801 to 1000. Data for each category of beekeeper in relation to average annual honey production per hive is provided in Figure 4.2.

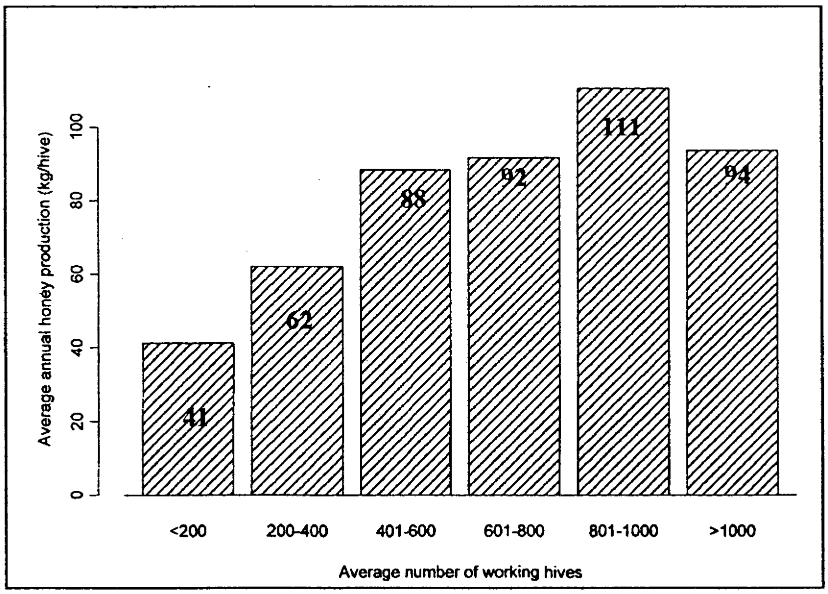


Figure 4.2 Average honey production (kg) per hive per year by number of hives managed.

Thirty responses from beekeepers owning less than 200 hives were recorded representing a small sample for this category, thus the average honey yield per hive should be viewed with some caution for this group. The average honey production per hive for all commercial beekeepers with 200 hives or more was 89.4 kg per hive per year.

Interstate movement: Interstate movement of hives has been occurring ever since beekeepers have had access to trucks, and has escalated as roads improved and trucks became bigger and more affordable. It was important to recognise the use of floral resources by interstate beekeepers, for a study of the distribution of residential addresses of beekeepers does not indicate the geographic distribution of the floral resources of significance to commercial beekeepers.

Of the 319 beekeeper responses, 118 indicated that they periodically travelled across State borders. Sixty-one NSW based beekeepers moved hives into Queensland and obtained 22% of their average five year annual honey production in Queensland. The percentage ranged from 1% to 60%. Seven Queensland based beekeepers moved hives into NSW and obtained 18% of their average five year annual honey production in NSW. The percentage ranged from 5% to 50%. Nine NSW based beekeepers moved hives into Victoria and obtained 12% of their average five year annual honey production in Victoria. The percentage ranged from 3% to 33%. Forty-one Victorian based beekeepers moved hives into NSW and obtained 35% of their average five year annual honey crop in NSW. The percentage ranged from 5% to 70%.

Floral species of primary importance to beekeeping in NSW

The most responses in the census were received for *Echium plantagineum* followed by *Eucalyptus melliodora, E. paniculata/E. siderophloia, Corymbia maculata/C. variegata, Brassica napus* and *E. macrorhyncha.* Colour plates are provided for these top six species, including Plate 4.1 *Echium plantagineum,* Plate 4.2 *Eucalyptus melliodora,* Plate 4.3 *Eucalyptus paniculata/E. siderophloia,* Plate 4.4 *Corymbia maculata/C. variegata,* Plate 4.5 *Brassica napus,* Plate 4.6 *Eucalyptus macrorhyncha.* A total number of 238 floral species were listed by beekeepers. The full list of all species mentioned in the surveys, listing the botanical name, common names and the number of responses is provided in Appendix 4.

Plate 4.1 Paddock of *Echium plantagineum* in full flower — Riverina, NSW

Plate 4.2 Mature *Eucalyptus melliodora* tree with commercial apiary in foreground — Southern Tablelands, NSW

Plate 4.3 A mature *Eucalyptus paniculata* tree with a commercial apiary in foreground — South Coast, NSW

Plate 4.4a *Corymbia maculata* bark — South Coast, NSW

Plate 4.4b *Corymbia maculata* blossom and foliage — South Coast, NSW

Plate 4.5 A paddock of *Brassica napus* in full bloom — Riverina, NSW

Plate 4.6 A mature *Euclayptus macrorhyncha* tree — Southern Tablelands, NSW.

The number of species mentioned by 20 or more beekeepers amounted to 51 species. A list of these species with the mean pollen value, the mean honey yield (kg) per hive, mean years between nectar flows and flowering period are presented in Table 4.3. Details for species mentioned by less than 20 beekeepers are not provided due to the diminishing accuracy expected with a smaller number of responses.

Geographic location of melliferous flora and the land tenure of apiary sites: The geographic location of melliferous flora on which apiary sites where located was stated by beekeepers by naming the nearest town, the distance and direction of the sites from that town. The distribution of each of the top 51 species is provided in map form in Appendix 5. The total number of sites relating to land tenure with an adjusted figure calculated by estimating the 19% non responses given the data for the 81% responses is provided in Table 4.4.

Table 4.4 The total number of apiary sites for each land tenure and an adjusted total to include estimates for non-respondents.

Land tenure	**Result from census (81% response)**	**Adjusted to include non-respondents (100%)**
State Forests	4,226	5,365
National Parks and Wildlife Service	333	412
Crown Land	569	749
Rural Lands Protection Boards	2,349	2,972
Private property	11,039	13,981
Total	18,516	23,479

Table 4.3 Floral species mentioned by 20 or more beekeepers with data specific to floral rewards obtained by honey bees, and flowering frequency (years) and range (months).

Species	Mean pollen value	Mean honey production kg/hive	Mean years between flowering events	Flowering event frequency (years)	Main flowering range (month)
Angophora floribunda	4.1	22	3.8	1-5	Dec-Feb
Arctotheca calendula	4.1	17	1.2	1-1	Aug-Nov
Banksia ericifolia	3.5	25	1.7	1-2	Apr-Aug
Brassica napus	4.3	21	1.2	1-5	Aug-Nov
Centaurea solstitialis	4.1	24	1.8	1-2	Dec-Mar
Corymbia gummifera	2.5	25	2.7	1-4	Jan-Apr
C. maculata/C. variegata	4.4	34	4.0	2-8	Jan-Aug
C. trachyphloia	4.0	42	2.0	2-4	Feb-Apr
Dillwynia spp.	3.9	9	1.3	1-2	Jul-Oct
Echium plantagineum	4.8	44	1.3	1-3	Oct-Dec
E. vulgare	4.6	27	1.8	1-2	Dec-Feb
Eucalyptus acmenoides	3.7	28	2.6	1-4	Sep-Jan
E. albens	3.0	44	2.7	1-5	Apr-Oct
E. andrewsii	3.6	42	2.9	2-4	Dec-Mar
E. blakelyi	4.1	24	4.2	2-5	Oct-Jan
E. bridgesiana	4.4	30	3.2	2-4	Jan-Apr

Table 4.3 cont.

Species	Mean pollen value	Mean honey production kg/hive	Mean years between flowering events	Flowering event frequency (years)	Main flowering range (month)
E. caleyi	2.0	36	3.3	2-3	Apr-Oct
E. caliginosa	4.0	33	3.1	2-5	Feb-Jul
E. camaldulensis	4.6	39	3.6	1-6	Nov-Jan
E. crebra	2.9	35	4.0	2-5	Sep-Dec
E. dealbata	4.4	27	3.4	2-5	Sep-Dec
E. fibrosa	2.1	40	4.0	2-5	Oct-Mar
E. globoidea	3.6	19	3.3	2-4	Aug-Oct
E. laevopinea	3.8	31	3.8	2-5	Jan-May
E. largiflorens	3.0	39	3.1	1-5	Nov-Feb
E. macrocarpa	2-4	26	4.2	2-5	Feb-Apr
E. macrorhyncha	3.9	35	3.6	2-5	Jan-Apr
E. melanophloia	3.2	52	4.1	3-4	Dec-Feb
E. melliodora	2.0	42	2.0	1-5	Oct-Jan
E. microtheca	3.5	47	2.8	2-4	Dec-Feb
E. moluccana	1.7	31	3.4	2-4	Feb-Mar
E. muelleriana	3.8	38	3.9	2-5	Dec-Mar
E. paniculata/E. siderophloia	1.8	54	2.6	1-5	Oct-Jan
E. pauciflora	4.2	35	4.0	2-5	Dec-Feb

Table 4.3 cont.

Species	Mean pollen value	Mean honey production kg/hive	Mean years between flowering events	Flowering event frequency (years)	Main flowering range (month)
E. pilularis	2.8	27	4.0	2-4	Nov-Apr
E. propinqua/ E. punctata	1.8	28	3.0	2-4	Jan-Mar
E. resinifera	3.2	17	3.0	2-4	Nov-Apr
E. saligna	3.7	32	4.6	2-5	Jan-Mar
E. sideroxylon	1.6	35	2.9	2-4	Mar-Oct
E. socialis	3.2	35	4.3	2-5	Dec-Jan
Eucalyptus spp. (stringybarks)	3.7	22	3.0	2-3	Jan-Dec
E. tereticornis	3.8	23	3.1	1-5	Jul-Nov
E. viminalis	3.9	18	3.9	2-5	Feb-Apr
E. viridis	2.3	53	3.2	2-4	Oct-Dec
Hypochoeris radicata	3.7	10	1.3	1-1	Oct-Feb
Lophostemon confertus	3.0	47	3.3	1-5	Nov-Feb
Medicago sativa	1.9	26	1.5	1-1	Dec-Mar
Melaleuca quinquenervia	4.2	33	1.3	1-2	Feb-Jun
Onopardum acanthium	3.1	29	1.5	1-2	Dec-Jan
Rapistrum rugosum	4.8	16	1.7	1-3	Jul-Oct
Trifolium repens	4.6	32	2.2	1-5	Sep-Jan

The land tenure of the apiary sites for the top 51 species are listed in Table 4.5. Sites are either private or public property. Public property can be divided into State Forests, National Parks, Crown Land or Rural Lands Protection Board reserves.

Table 4.5 Land tenure of apiary sites from which the top 51 floral species are sourced for nectar and pollen.

Species	State Forests	National Parks and Wildlife Service	Crown Lands	Rural Lands Protection Boards	Private property	Total
Angophora floribunda	43	0	6	16	157	222
Arctotheca calendula	5	0	5	23	141	174
Banksia ericifolia	45	73	17	0	53	188
Brassica napus	8	0	0	107	831	946
Centaurea solstitialis	0	0	1	79	259	339
Corymbia gummifera	299	13	12	11	280	615
C. maculata/C. variegata	823	25	5	19	403	1275
C. trachyphloia	204	25	2	9	158	398
Dillwynia spp.	57	2	13	0	100	172
Echium plantagineum	38	0	19	439	1602	2098
E. vulgare	14	0	2	25	137	178
Eucalyptus acmenoides	350	17	3	35	325	730
E. albens	44	15	24	220	914	1217
E. andrewsii	45	35	5	34	166	285
E. blakelyi	15	11	18	59	242	345
E. bridgesiana	34	1	2	22	336	395
E. caleyi	22	0	12	27	120	181

Table 4.5 cont.

Species	State Forests	National Parks and Wildlife Service	Crown Lands	Rural Lands Protection Boards	Private property	Total
E. caliginosa	57	20	26	73	506	682
E. camaldulensis	201	0	23	152	361	737
E. crebra	191	29	26	30	192	468
E. dealbata	78	13	9	68	290	458
E. fibrosa	261	29	2	8	177	477
E. globoidea	148	1	9	2	51	211
E. laevopinea	69	22	0	37	112	240
E. largiflorens	36	22	38	61	280	437
E. macrocarpa	39	1	11	75	215	341
E. macrorhyncha	106	16	13	61	722	918
E. melanophloia	19	5	0	113	267	404
E. melliodora	40	0	21	369	1440	1870
E. microtheca	8	22	12	93	273	408
E. moluccana	81	0	2	14	127	224
E. muelleriana	209	1	2	3	36	251
E. paniculata/E. siderophloia	975	23	6	53	572	1629
E. pauciflora	41	4	0	11	89	145
E. pilularis	218	13	5	6	165	407

Table 4.5 cont.

Species	State Forests	National Parks and Wildlife Service	Crown Lands	Rural Lands Protection Boards	Private property	Total
E. propinqua/ E. punctata	212	7	0	5	117	341
E. resinifera	64	1	0	4	77	146
E. saligna	132	5	1	2	47	187
E. sideroxylon	168	18	2	49	539	776
E. socialis	24	0	8	9	93	134
Eucalyptus spp. (stringybarks)	57	7	0	2	91	157
E. tereticornis	150	2	6	28	218	404
E. viminalis	59	4	2	27	171	263
E. viridis	2	0	4	24	170	200
Hypochoeris radicata	13	0	1	5	81	100
Lophostemon confertus	509	38	0	18	238	803
Medicago sativa	0	0	1	33	170	204
Melaleuca quinquenervia	40	37	17	5	179	278
Onopardum acanthium	0	0	1	23	171	195
Rapistrum rugosum	0	0	10	263	316	589
Trifolium repens	16	0	0	121	732	869

DISCUSSION

Response to surveys: The number of forms completed and returned was quite exceptional, providing strong validation for the aggregated data. Normally a 25 to 35% response to a survey is considered acceptable. An 81% response is exceptional, particularly given that commercial beekeepers are generally reluctant to relinquish a lifetime of knowledge on the benefits of various floral species to the management of their apiaries, especially the locations of the floral resources utilised.

Even though only 65% of the beekeepers in the 200–400 hive ownership group returned their forms, the non response from the 80 beekeepers probably only accounts for data from 320 apiaries calculated by assuming an apiary was comprised of 100 hives. These apiaries on average would be moved a reduced number of times as compared to the larger beekeeping operations based on honey produced per hive data. The 200-400 hive ownership group probably only move hives, on average three times, accounting for 960 sites not accounted for in this report. Given that the total number of apiary sites provided by the census was 18,516, the missing data should not significantly influence the results.

Number of production hives: Commercial beekeepers, or those managing greater than 200 hives, only represent 10–11% of all the registered beekeepers in NSW. This study was primarily concerned with the group owning 200 hives or greater, as their mobility, use of and reliance on floral resources was far greater than the 1–199 hive group. Although beekeepers who own 40 to 199 hives move them on a limited basis, their individual reliance on floral resources is not as significant as larger commercial operations. This group (40–199 hives) managed approximately 15% of the hives within NSW. Beekeepers with less than 40 hives managed 9% of the State's hives and their overall production per hive would be low, probably less than 20 kg per hive per annum. The results of the survey represent 167,790 hives—an adjusted figure taking into account non-respondents was 206,522 hives for the group of beekeepers with 200 plus hives. This compares very well with the figures from the NSW Agriculture Beekeeping Registration System in 1997 and 1999 with only a 2% to 3% variation between the three figures. The following Table 4.6 provides the total number of hives registered for each category of beekeeper in NSW.

Table 4.6 The number of producers and total hive numbers per hive category for January 1997 and April 1999 as obtained from the NSW Agriculture beekeeping registration system.

	7 January 1997		21 April 1999	
Hive category	**Producers**	**Total hive numbers**	**Producers**	**Total hive numbers**
<40	3,180	24,458	2,889	23,010
40–200	499	41,158	476	40,030
200–500	253	75,636	265	79,328
500+	160	124,382	150	121,677
Totals	**4,092**	**265,634**	**3,780**	**264,045**

Honey production per hive: Honey production per hive will vary according to seasonal conditions such as drought, the beekeepers' management abilities/strategies, and the available floral resources within economic travelling range. Production will vary from beekeeper to beekeeper and from apiary to apiary. Each colony's ability to collect and store surplus honey will vary significantly within the one apiary, even if all other external factors on the colony are similar.

The results indicate that the average honey production per hive increased with the number of hives managed. Honey production has been stated as being 100 to 150 kg per hive per year, with an average production per hive of 120 kg for a skilled operator (Hornitzky *et al.* 1993), whereas reports from the Australian Honey Board (1990, 1991, 1992) indicated a much lower yield per hive. The following Table 4.7 provides the average honey production per hive in kilograms as published by the Australian Honey Board.

Table 4.7 Average production per hive according to Australian Honey Board reports from 1989 to 1992.

Report	**No. of beekeepers**	**Average production per productive hive (kg)**
91/92	256	75.5
90/91	333	67.8
89/90	348	75.9

(Australian Honey Board 1990, 1991, 1992)

The results show that the beekeepers managing 200 to 400 hives averaged 62 kg per hive, whereas the top figure was 111 kg per hive managed by beekeepers with 801 to 1000 hives. The average across all groups was 89.4 kg per hive. The number of beekeepers within the 200 to 400 hive group was far greater than that of the other groups with more than 400 hives, thus when the averages are included for all beekeepers, the mean for all groups is drawn closer to the 200 to 400 hive category. An estimate of the honey production per hive from the data and other published sources indicated an average between 60 kg to 90 kg per year. In good years, better managers may be expected to obtain up to 150 kg per hive or greater.

Interstate movement: It is interesting to note that there is a general movement of southern based beekeepers north, and significantly less movement south. There were 61 NSW based beekeepers who obtained, on average, 22% of their average five year honey production from Queensland floral resources. Yet, there were only seven Queensland based beekeepers who obtained, on average, 18% of their average five year honey production in NSW. Likewise, a similar situation occurred on the southern border with Victoria. There were 41 Victorian-based beekeepers who obtained 35% of their average five year honey production in NSW, whereas only nine NSW based beekeepers obtained 12% of their average five year honey production in Victoria. The number of Victorian based beekeepers working NSW floral resources was very significant, given that there were 41 responses and, on average, 35% of their honey production was obtained in NSW. This would indicate that the floral resources in the Riverina area of southern NSW are utilised extensively by beekeepers not residing in NSW.

Floral species of primary importance to beekeeping in NSW: Arguably, this is the most important information collected in the study. Previous to this authors have listed a range of floral species of value to honey bees (Rayment 1934; Goodacre 1947; Clemson 1985) without identifying the significance of each floral species in the context of the melliferous flora of NSW.

The results highlight the floral species that were the most reliable and abundant, producing significant quantities of pollen and/or nectar. A total of 238 species were mentioned by one or more beekeepers, although only 51 species were mentioned by more than 20 beekeepers. Of the 51 floral species mentioned by 20 or more beekeepers, 41 were indigenous (80%) comprising 33 (65%) eucalypts, four related species, two other tree species and two shrubs. Introduced species accounted for ten species (20%) including seven weeds and three species of agricultural importance. The group of floral species mentioned by less than 20 beekeepers would be extremely important to individual beekeepers, as a viable beekeeping business requires access to a diverse range of floral species, many of which may be localised. A large scale study is more likely to document the abundance of certain melliferous flora rather than providing detailed data on every melliferous floral species. For the purpose of comparison the top six species including *Echium plantagineum*, *Eucalyptus melliodora*, *E. paniculata/E.siderophloia*, *Corymbia maculata/C. variegata*, *Brassica napus* and *E. macrorhyncha* will be reviewed, although comprehensive discussion of these species will be provided in Chapter 8 incorporating the results from Chapter 5 and 6.

Echium plantagineum, unquestionably was the most important floral species supporting beekeeping interests in NSW, yet this species is regarded as a weed by a large proportion of the pastoral industry. Clemson (1985) certainly recognised the value of this species to NSW beekeepers yet Goodacre (1947) only gives it passing mention indicating it is useful as a spring stimulant for brood rearing, similar to the comments attributed by Rayment (1934), that it yields honey but hardly sufficient to store much in the supers.

Eucalyptus melliodora was mentioned by beekeepers from Queensland to the Victorian border and has an extensive geographic distribution across the tablelands and Western Slopes. Clemson (1985) mentions that this species was once regarded as the State's best honey tree in terms of quantity of honey produced but due to the clearing of agricultural lands this is no longer so. Goodacre (1947) on the other hand states that the species was the best honey tree in the world, combining quality and quantity of production. This sentiment was still the case thirteen years earlier when Rayment (1934) stated that it was the most popular honey tree in Australia.

Eucalyptus paniculata/E. siderophloia both refer to Grey ironbark as a common name in use by beekeepers. This tree has only recently been split into a northern and southern species with significant geographic overlap. The distribution of the species as stated by beekeepers ranged from Narooma in the south to the Queensland border. Clemson (1985) states that the tree is the most valuable ironbark to beekeepers on the coast, whereas Goodacre (1947) indicates that it is the most valuable ironbark species in

NSW, yet Rayment (1934) only give it passing mention.

Corymbia maculata now refers to the Spotted gum on the Central and South Coast of NSW, whereas *C. variegata* is the botanical name recently given to the tree in the northern regions of NSW. This is certainly a species of major importance the length of coastal NSW, although the frequency of flowering (4 years between flowering events) was a lot greater than many eucalypt species. Weather conditions play a major role in the floral rewards obtained by honey bees. In the southern coastal region, flying durations are restricted due to low temperatures or unfavourable weather plus shorter day length during winter (Clemson 1985). Goodacre (1947) provided information on Spotted gum, known as *Eucalyptus maculata*, although he did not give the tree exalted status. Rayment (1934) stated that the tree Spotted gum, then known as *Eucalyptus haemastoma*, was of considerable value to apiarists, although it only flowers every three years.

The value of *Corymbia maculata* to beekeepers was probably a factor of the season in which it flowered, i.e. autumn and winter and the lack of other flowering species in the State from which beekeepers may choose. Thus without local floristic choices beekeepers from inland NSW would find the movement of hives to the coast onto this species very beneficial when there is limited or no other choice for honey bees to gain access to flowering plants. This scenario would make Spotted gum sites of high value to beekeepers due to the restricted distribution of the species and reduced access to the species due to the coastal terrain and land tenure.

Brassica napus is a widely cultivated oil seed crop throughout the broad acre cropping areas of NSW, grown in rotation with wheat. Its main attraction was the predictable flowering behaviour and the known area that is annually sown to the crop. This allows a calculated stocking rate of hives per hectare in order not to over-saturate an area with honey bees, potentially reducing the floral rewards per colony. As the crop is sown in the late autumn, beekeepers are readily able to identify areas that will be in flower in the early spring. The current abundance and popularity of *Brassica napus* to the cropping industry ensures that this resource is not limiting and there is ample blossom available for all commercial beekeepers who seek this flowering event.

Brassica napus and *Brassica campestris* were both available to beekeepers (Clemson 1985), although the later has lost favour as a cropping species in more recent times. Clemson also indicated that this species was an important source of honey in countries where it was grown. In the NSW context its main value was in providing copious quantities of pollen and stimulating nectar to encourage the expansion of populations in September prior to the main honey production season in much of the State starting in October. Brassicas do not rate a mention by Goodacre (1947) and only score a brief mention by Rayment (1934), indicating that only small yields of honey are obtained occasionally.

Eucalyptus macrohyncha has a wide distribution extending from the Queensland to Victorian borders, predominantly on the tablelands. Given the status of the species to beekeepers, the years between flowering events was significant at three to four years on average. Its main value, given that it flowers in the autumn, was the reduced competition from other flowering events at the same time. This was made mention of in the case study in Chapter 2. Clemson (1985) indicated that *E. macrohyncha* was not a reliable honey producer thus reducing its level of importance. Perhaps he has underestimated its value to the NSW beekeeping industry. On the other hand Goodacre (1947) speaks favourably of the species indicating that yields of up to 120 lbs (54 kg) per colony average can be obtained and that good wintering of colonies can be anticipated. The regularity of the flowering of this tree would seem to be at least, historically more frequent in Victoria, where it flowers every other year (Rayment 1934), although bumper honey crops are obtained every three years with harvests of up to 160 lbs (73 kg) per hive.

There is evidence from this study when compared to previous reports on individual species that over the last 50 years, *Echium plantaginum* has risen in importance from a very low level to be a species of major importance. This is probably due to its spread as an agricultural weed, possibly aided by the movement of contaminated hay. *Eucalyptus melliodora* and *E. macrorhyncha* have been reduced in status although it is not possible to gauge by how much in this study. *E. paniculata/E. siderophloia* and *Corymbia maculata/C. variegata* have probably retained a similar status to commercial beekeepers within NSW and *Brassica napus* has increased its share of beekeeping importance due primarily to its increasing abundance in the wheat growing areas of the State.

There were 12 species with honey production levels above 40 kg per hive. These are listed in Table 4.8 with the most frequently mentioned species *Echium plantagineum* with 191 responses to *Eucalyptus andrewsii* with 27 responses. The production levels in Table 4.8 are the means only. There will be flowering events when honey production levels will be considerably less than the mean and also in favourable years the production will be considerably higher per hive for each species. The level of honey production for each species is supported by comments published by Clemson (1985), these have been included in Table 4.8.

Table 4.8 Species with mean honey production above 40 kg per hive, comparison with comments published by Clemson (1985).

Species	**Kg of honey/hive**	**Comments from Clemson (1985)**
Corymbia trachyphloia	42	Medium importance
Echium plantagineum	44	The most valuable herbaceous plant for beekeepers in southern NSW
Eucalyptus albens	44	Major source of honey
E. andrewsii	42	Major source of honey, 30–60 kg/ hive
E. fibrosa	40	Medium value for honey production
E. melanophloia	52	Capable of producing a heavy crop of honey spasmodically
E. melliodora	42	Once regarded as the State's best honey tree
E. microtheca	47	Medium to major source of honey
E. paniculata/E. siderophloia	54	May produce 60–80 kg/hive
E. viridis	53	Major honey producer
Lophostemon confertus	47	Major producer of nectar

Pollen: Pollen values as stated in this study may have various interpretations. When a beekeeper was asked what value they gave pollen from a particular floral species, they may have been referring to the quantity of the pollen available or the quality of the pollen, (crude protein and other nutritional attributes) or a combination of both, i.e. its overall impact on colony health. It may also refer to the availability of pollen at times of the year when pollen sources were scarce. It was more likely that the majority of pollen values were expressed as a combination of both quality and quantity.

The ironbarks and *Eucalyptus melliodora* were rated as very low for pollen. A very small minority of beekeepers gave values for pollen from medium to high for some species when the majority of responses indicated very low or non-existent values for the same floral species. The few beekeepers who rated these species medium to high, may have been referring to the floral species flowering at the same time as the low value pollen species. The ironbark group of eucalypts and *E. melliodora* received very low numbers of responses for the value of pollen, indicating that many beekeepers regarded these species as having a zero value as a source of pollen, which was not apparent in the results.

Floral species with pollen valued from 4 to 5 could be regarded as very important for their contribution to honey bee nutritional requirements (Table 4.9). Of the species mentioned by more than 20 beekeepers, 16 floral species or 31% of the top 51 species were regarded as being of high significance as a source of pollen. These are listed in Table 4.9. Seven of these 16 species were introduced plants either considered agricultural crops (*Brassica napus*), pasture plants (*Trifolium repens*) or agricultural weeds (*Arctotheca calendula, Centaurea solstitialis, Echium plantagineum, E. vulgare and Rapistrum rugosum*). Eight species were eucalypts or *Corymbia* species and *Melaleuca quinquenervia* made up the total of 16 species. The values placed on these floral species as significant sources of pollen are supported by comments by Clemson (1985) as listed in Table 4.9.

Table 4.9 Species with pollen values above 4 out of a possible rating of 5 from 20 or more responses, comparison with comments published by Clemson (1985).

Species	Pollen value	Comments from Clemson (1985)
Angophora floribunda	4.1	Major source
Arctotheca calendula	4.1	Bees gather giant loads
Brassica napus	4.3	Pollen attractive to bees
Centaurea solstitialis	4.1	Excellent source
Corymbia trachyphloia	4.0	Medium to major source
C. maculata	4.4	Heavy supplies of pollen
Echium plantagineum	4.8	Major source
E. vulgare	4.7	Good source
Eucalyptus camaldulensis	4.6	Major source
E. blakelyi	4.1	Major source
E. bridgesiana	4.4	Abundance of pollen
E. dealbata	4.4	Major importance
E. pauciflora	4.2	Good supplies
Melaleuca quinquenervia	4.2	Major source
Rapistrum rugosum	4.8	Major source
Trifolium repens	4.6	Moderate to large quantities

Flowering event frequency: The dryness of the Australian climate and the sporadic flowering behaviour of our major floral resources, mainly eucalypts, make Australian commercial beekeeping unique. No one year is identical and frequently many of the floral species worked by commercial beekeepers are significantly different from year to year. Many eucalypt species have a flowering cycle that extends over two or more years. Even the herbaceous plants such as agricultural weeds and crop species are not consistently reliable, as weather influences have a large impact on plant health and nectar secretion.

Beekeepers were asked in this study to state the "years between flows". The majority of responses for this question will reflect the actual flowering cycle of the species. However the reliability of the species to yield quantities of nectar and pollen may vary due to other factors such as drought or excessive growth, both potentially reducing nectar yields obtained by honey bees. This would influence the stated period between flows, not relating to every flowering event.

A species may not be actively sought by beekeepers on every occasion on which it flowers, thus some beekeepers may have approached this question by stating the period of years between reliable or worthwhile nectar flows, when they have worked this floral source. It is possible that the frequency and reliability of a species to flower and yield nectar will be greater in one location than in another location, due possibly to climatic variables and soil type/fertility. Some species, e.g. *Corymbia maculata*, initiate buds and flower some 18 months later. This species has not been observed to carry two sets of buds, so it is not possible for the same tree to flower each year, whereas if different trees are initiating buds in different years in the same area, then it is possible that beekeepers could have access to the one species on consecutive years. Some eucalypt species do have the capacity to carry sets of buds for consecutive years.

Land tenure of apiary sites

State Forests: For State Forests, the total number of sites, adjusted to include those beekeepers who did not respond to the survey, was 5,365, whereas the total number of sites for which permits were issued in 1995/96 was 3,749 (State Forests 1996). The difference of 1,616 sites could be due to two sites on the one permit or, the temporary use of sites within State Forests due to varying floral prospects over the last five years. The context of the question to beekeepers in the survey was, "How many sites in total have you occupied .... in the last five years?". In this case, a beekeeper may have occupied a site and paid for that permit for only a one year period during that time frame. From the various studies on beekeeping in State Forest districts (refer chapter 5), most permits were for a 12-month period. Even so, from the results of the survey, there was an indication that possibly 1,500 sites in State Forests were paid for and occupied on a casual basis over a five year period. State Forests represent 23% of all bee sites in NSW.

The following Table 4.10 provides a list of the species of major importance to NSW beekeepers available from sites located on NSW State Forests. Over 10 species have greater than 50% of the apiary sites within NSW located on State Forests. These include: *Corymbia maculata/C variegata, C. trachyphloia, Eucalyptus fibrosa, E. globoidea, E. muelleriana, E. paniculata/E. siderophloia, E. pilularis,* *E. propinqua/E. punctata*, *E. saligna* and *Lophostemon confertus.*

Table 4.10 Species mentioned by 20 or more beekeepers with greater than 20 per cent of the sites of that species located in NSW State Forests.

Species	Sites in State Forests	Percentage of total sites in NSW for species
Eucalyptus paniculata/ E. siderophloia	975	60
Corymbia maculata/ C. variegata	823	65
Lophostemon confertus	509	63
E. acmenoides	350	48
C. gummifera	299	49
E. fibrosa	261	55
E. pilularis	218	54
E. propinqua/E. punctata	212	62
E. muelleriana	209	83
C. trachyphloia	204	51
E. camaldulensis	201	27
E. crebra	191	41
E. sideroxylon	168	22
E. tereticornis	150	37
E. globoidea	148	70
E. saligna	132	71
E. moluccana	81	36
E. laevopinea	69	29
E. resinifera	64	44
E. viminalis	59	22
Eucalyptus spp. (Stringybark)	57	36
Dillwynia spp.	57	33
Banksia ericifolia	45	24
E. pauciflora	41	28

Rural Lands Protection Boards: A survey of the 57 Rural Lands Protection Boards (RLPB) (Somerville 1997) indicated 2,889 sites leased to beekeepers along the various travelling stock routes and reserves. The data collected in this study during a similar time frame indicated 2,972 sites, thus the figures were sufficiently close enough to support each other. The primary floral resources on or worked by honey bees from these sites are included in Table 4.11. The single most important floral species was *Rapistrum rugosum*, mainly occurring in the North West Slopes and Plains of NSW. Of the species mentioned by 20 or more beekeepers, eight species had at least 20% of the sites in NSW for these species.

Table 4.11 The main floristic species utilised by beekeepers on Rural Lands Protection Board lands

Species	Sites on RLPBs	Percentage of total sites in NSW for species
Echium plantagineum	439	21
Eucalyptus melliodora	369	20
Rapistrum rugosum	263	45
E. camaldulensis	152	21
E. melanophloia	113	28
E. microtheca	93	23
Centaurea solstitialis	79	23
E. microcarpa	75	22

Other species with over 100 sites on RLPB reserves, with less than 20%, but more than 10% of the total number of sites for these species include: *Brassica napus* (107 sites); *Eucalyptus albens* (220 sites) and *Trifolium repens* (121 sites). Although *Brassica napus* does not occur on the RLPB land tenure, honey bees access *Brassica napus* blossom in neighbouring private property. One point worthy of note is that RLPB reserves are often favoured due to their vehicle accessibility and suitable sites to place hives.

National Parks: The number of sites used by beekeepers has been stated by National Parks to be 163 in August 1995 and 319 in February 1998 (Somerville 1999b). The collection of data for this study was conducted between mid-1997 and late 1998. It is possible, and highly probable, that more areas of land tenure have been added to the

National Park estate over the duration of this study and thus, the adjusted figure of 412 sites on National Parks is probable. The total of 333 sites from the survey is similar to previous figures stated by National Parks and Wildlife Service sources. It is possible that the remaining beekeepers who did not respond to the survey had significantly less than the 79 sites combined in National Parks. Bee sites on Water Board land tenure are managed by National Parks which may increase the number of sites stated as National Park sites by some beekeepers.

One floristic species stands out as a major floral resource with a large number of sites within National Parks. There were 73 sites on *Banksia ericifolia* in National Parks, representing 39% of all sites available for this species. The following floral species had 20 or more sites accessed by beekeepers from National Parks: *Corymbia maculata/C. variegata, C. trachyphloia, Eucalyptus andrewsii, E. caliginosa, E. crebra, E. fibrosa, E. laevopinea, E. largiflorens, E. microtheca, E. paniculata/E. siderophloia, Lophostemon confertus* and *Melaleuca quinquenervia.*

The large differences in number of sites between State Forests (5,365) and National Parks (412), given similar areas of crown lands managed (Somerville 1999b), can be attributed to two factors. As the main role of State Forests is to harvest timber, the network of roads necessary to serve this function provides excellent access for beekeepers, also old log dumps along side these roads offer satisfactory locations to place hives. The National Park system on the other hand has a limited roading system, primarily for visitor access to major attractions and does not have a patch work of old log dumps that would make suitable apiary sites. Compounding this reduced physical access is the policy direction of National Parks (Somerville 1999b) which has generally been unfavourable to encouraging the continuation of beekeeping within park lands.

Crown Lands: This land tenure encompasses many different land tenures including the Department of Land and Water Conservation, Western Lands leases, Roads and Traffic Authority, town commons, and Water Board sites. Some crown lands are periodically transferred to State Forests and National Parks. Where there are more than 20 crown land lease sites for the one floristic species in western NSW, it is likely that most of these sites were Western Lands leases. There were more than 20 crown land sites with the following floral species: *Eucalyptus albens, E. caliginosa, E. camaldulensis, E. creba, E. largiflorens, E. ochropholia* and *E. populnea.*

Private property: The total adjusted number of apiary sites on private property was 13,981, which represents 60% of all sites, making it the most important land tenure in NSW. Of the species mentioned by 20 or more beekeepers, 33 out of 51 had over 50% of their sites on private property. *E. camaldulensis* is marginal, with 49% of the sites on private property. Apiary sites working pasture weeds and agricultural crops were dominantly private property. Floristic species with over 80% of their sites on private property included: *Arctotheca calendula, Brassica napus, Eucalyptus bridgesiana, Hypochoeris radicata, Medicago sativa, Onopordum acanthium* and *Trifolium repens.* It is interesting to note that of *E. bridgesiana* sites, largely (85%) occur on private property—the greatest level for any Australian native species of major importance to commercial beekeeping interests in NSW.

This study identified 51 floral species on a State-wide basis that hold the positions of the most importance to commercial beekeeping interests. As such, any activity that affects the health of these species, abundance or accessibility by beekeepers will most probably impact on the management strategies, honey yields and financial viability of many beekeepers within NSW and in some circumstances beekeepers in adjacent States. The contribution of eucalypts to beekeeping in NSW is highly significant, given that their flowering frequency is sporadic and spread over a number of years. This in essence sets the NSW beekeeping calendar apart from the international beekeeping scene.

CHAPTER 5

DISTRICT FOREST SURVEYS

INTRODUCTION

The melliferous flora of New South Wales (NSW) can be found on a range of land tenures including State Forests. The previous chapter (Chapter 4) provided evidence of the number of sites utilised by commercial beekeepers registered in NSW over a five year period within each land tenure. A separate study with the purpose of documenting only the floral resources of importance to beekeepers was conducted between 1990 and 1997 for each State Forest district. This set of data provided verification of the floral species of primary importance to NSW beekeepers occurring in NSW State Forests as identified in Chapter 4.

The State forests of New South Wales (NSW) represent an extremely important resource for the NSW beekeeping industry. In 1995/96 there were 3,749 occupation permits issued for bee farming in NSW State forests (State Forests 1996), this rose slightly to 3,843 permits in 1997 (Smith 1999). On average, 70% of the honey production obtained by beekeepers was derived from eucalypt or closely related species in NSW (Somerville and Moncur 1997). Much of the accessible forested lands of NSW are located in the State forests of NSW.

Commercial beekeepers in NSW manage, on average, 500 hives varying from 350 to 700 hives. An average production yield for a skilled operator is 100 to 120 kilograms per year per hive. To achieve this, hives are transported from one location to the next. Most beekeepers operate within 200 km from home base for most of the year, with occasional trips outside of this range to particularly good and reliable nectar flows, for over wintering conditions, or to escape drought conditions closer to home base. Hives may be shifted four to six times per year on average onto surplus nectar producing flora (Hornitzky *et al.* 1993). Commercial beekeeping is a family based rural industry and is highly labour intensive.

Commercial beekeepers require access to an extensive network of floral sources to be able to move hives onto nectar producing flowering plants on a regular basis. On average 100 to 120 hives are located at each site. A commercial beekeeper with 500 to 600 hives will require five or six sites for each floral species.

Many eucalypt species, from which nectar is periodically harvested by honey bees, flower on a two to four year cycle. Some eucalypts have a longer flowering cycle, based on beekeeper observation (Somerville 1999a). Even though a species is flowering and it has been identified as a useful floral resource for beekeeping purposes, the climatic conditions may not be suitable for nectar secretion. Thus beekeepers may only work a particular floral species every second or third flowering period. Yields from the one species will also vary according to location, climatic factors, and strength of the foraging force of the colony (Clemson 1985).

Careful management decisions by beekeepers have to be continually made in relation to honey bee nutritional requirements. Honey bees obtain their carbohydrate from nectar, which they convert into honey, whereas their protein source is derived from pollen and varies significantly in quality. The volume of nectar produced by each species and the sugar content of the nectar varies considerably due to a range of variables. Honey bees can distinguish nectars with higher sugar levels and favour their collection (von Frisch 1950).

A number of important nectar floral resources notably do not produce pollen that is attractive to honey bees. Some classic eucalypt examples include *Eucalyptus paniculata* (Grey ironbark), *E. sideroxylon* (Mugga ironbark) and *E. melliodora* (Yellow box) (Clemson 1985). Yet other eucalypts provide pollen that is attractive to honey bees but it is considered poor quality in relation to satisfying honey bee nutritional requirements. Honey bees require pollen with at least a 20% protein content to maintain breeding. *Eucalyptus albens* (White box), an important nectar source on the Northern Tablelands of NSW, produces a pollen with protein levels of 17% causing significant management problems (Kleinschmidt and Kondos 1976). A mix of floral resources within the foraging range of a colony is important for honey bees to satisfy their nutritional requirements and reduce any deficiency associated with a single pollen source.

Extensive amounts of time can be invested by beekeepers seeking apiary sites. A network of high quality apiary sites covering a large diversity of reliable nectar and pollen producing plants within economic travelling distance of a beekeeper base is a desirable goal for all commercial and semi-commercial beekeepers. State Forests of NSW allow beekeepers to place apiaries within public forests where sites are defined by suitable locations to place hives and suitable vehicle access. Commercial beekeepers require all weather access to be able to adequately manage honey bee colonies and the public forests managed by State Forests of NSW provide an ideal set of circumstances as a consequence of their principal management of forests for timber harvesting. Old log dumps also offer excellent sites for the location of large numbers of hives. State Forests of NSW offer a network of suitable sites for the placement of hives where often more than one species can be worked in different years, the same year or concurrently.

MATERIALS AND METHODS

Information was collected by conducting a series of surveys of the beekeepers with beekeeping occupation permits, recorded at 31 NSW State Forest district offices between 1990 and 1997. The survey was a collaborative effort with the various State Forests of NSW district foresters. The number of beekeepers with permits for each State Forest district varied from one beekeeper (Bombala) to 80 beekeepers (Batemans Bay).

Names and addresses for all apiary permits for each State Forest district were obtained from each district office. For every district a survey form and covering letter was sent to each beekeeper and in some districts with reduced beekeeping activity, to beekeepers who had permits in immediate past years. Most responses were by return of the survey form. Key beekeepers with significant numbers of apiary permits were interviewed either in person or by phone to ensure the number of responses accounted for the majority of apiary permits issued for each district.

The survey form was composed of two parts. The first section asked the beekeeper to list the floral species of importance in that particular forest district. The questions included:

- species (common or scientific name)
- level of importance of honey/pollen - low, medium, high
- expected yield (tins) [a tin is an historical measurement used by beekeepers to

indicate the yield of honey per hive. A tin is equivalent to 27 kg]

- time of year flowering occurs and duration buds are carried
- how many years between nectar flows
- stocking rate (hives per site)

The second section asked more general questions which included:

- information on history of usage
- comments on forestry practices, as they relate to beekeeping activities (likes or dislikes)
- how many sites do you have in _ _ _ _ forestry district?
- State Forest sites
- private property adjoining State forests
- comments on changed flowering or yielding patterns of forest flora, impacting on honey production
- how do these forests fit into your annual calendar of activities?
- other comments?

The surveys for each Forestry district were staggered over a number of years. An initial pilot survey in 1990 (Nowra State Forests) was simple in design, asking for information on the floral species of importance to beekeeping. The next districts surveyed were sent the questions from section one only, they included Batemans Bay, Baradine, Central Murray and Queanbeyan/Badja. The Baradine survey, although initially part of the study, was the only district in which the survey design differed substantially from the rest of the State (Stace 1996b). The remainder of the forestry districts surveyed were conducted during 1996-1997 and included the questions from both section one and two.

The principal reference for botanical names was the Royal Botanic Gardens (Anon. 2004). There continues to be discussion concerning *Corymbia* species, the botanical names referenced are as published by the Royal Botanic Gardens.

RESULTS

Survey statistics

The following tables summarise the results of 26 reports based on beekeeping information supplied in the completed surveys. In most cases a 70 to 80% response was obtained, initially by a mail survey, a personal interview or phone survey. Due to only occasional usage of some State Forest districts by beekeepers, some of the data was amalgamated with adjacent districts. These combinations included Bathurst/Oberon, Eden/Bombala, Queanbeyan/Badja, Tumut/Tumbarumba and Walcha/Gloucester.

State beekeeper analysis

The commercial status of beekeepers can be divided into four categories: 1-39 hives amateurs; 40-199 hives part time; 200-399 hives full time [although not considered sufficient numbers in most cases to provide a sole income] and 400 plus hives full time. From Table 5.1. amateur and part time beekeepers occupied less the 10% of the total number of forestry sites, where as the group of beekeepers managing the greatest number of hives occupied the greatest number of forest sites at 67%.

Table 5.1 The category of beekeeper issued with beekeeping occupation permits in 24 NSW State Forest districts.

	Amateur 1-39 hives	Part time 40-199 hives	Full time 200-399 hives	Full time 400 hives plus
Percentage of beekeepers	3%	14%	23%	60%
Number of beekeepers	(20)	(91)	(148)	(393)
Percentage of sites issued to each group	<1%	9%	23%	67%

Responses to survey questions – section 1

Stocking rates: The number of hives per site varied considerably from 35 to 300 hives. The mean number of hives per site ranged between 100 and 120 hives per site. Only a few beekeepers varied the stocking rates according to the nectar and pollen yielding capacity of the flora.

The primary melliferous flora by forestry district: The most frequently mentioned floral species were of prime importance to beekeepers in each State Forest district. The first three most frequently stated species are provided in Table 5.2. These can be attributed to either the abundance of that species in that Forest district or the high level of reliability of that species to yield surplus nectar.

A number of species were mentioned in more than one district. The South Coast districts were particularly favoured for *Corymbia maculata, Eucalyptus longifolia* and *E. muelleriana*. The tablelands were favoured for *E. viminalis* and *E. pauciflora*. The Riverina region for *Echium plantagineum, Eucalyptus camaldulensis* and *E. largiflorens.* The ironbarks including *E. sideroxlon, E. fibrosa* and *E. beyeri* were favoured in the central and northern areas of the western forests. The Central and North Coast forests were favoured for *E. acmenoides, E. paniculata* and *E. siderophloia.* Other North Coast species most favoured included *C. variegata* and *Lophostemon confertus*.

Table 5.2 The three most frequently stated melliferous floral species of importance to beekeeping in each State Forest district. (Walcha/Gloucester district not include due to small sample)

Forestry district	1st	2nd	3rd
South Coast:			
Eden/Bombala	*Eucalyptus muelleriana*	*E. globoidea*	*E. longifolia*
Narooma	*E. muelleriana*	*Corymbia maculata*	*E. longifolia*
Batemans Bay	*Corymbia maculata*	*E. paniculata*	*E. saligna*
Nowra	*Banksia ericifolia*	*C. gummifera*	*C. maculata*
Tablelands:			
Tumut / Tumbarumba	*E. pauciflora*	*E. delegatensis* equal 1st	*E. viminalis*
Queanbeyan / Badja	*E. pauciflora*	*E. viminalis*	*E. fastigata*
Bathurst / Oberon	*E. macrorhyncha*	*E. viminalis*	*Echium vulgare*
Inverell	*E. melanophloia*	*E. albens*	*E. crebra*
Western region:			
Central Murray	*E. camaldulensis*	*E. largiflorens*	*Echium plantagineum*
Mildura	*E. largiflorens*	*E. camaldulensis*	*E. dumosa/ E. incrassata*
Narrandera	*E. camaldulensis*	*E. melliodora*	*Echium plantagineum*
Forbes	*E. sideroxylon*	*E. microcarpa*	*E. fibrosa*
Dubbo	*E. crebra*	*E. beyeri*	*E. sideroxylon*

Table 5.2 cont.

Forestry district	1st	2nd	3rd
Baradine (Pilliga)	*C. trachyphloia*	*E. fibrosa*	*E. crebra*
Central Coast:			
Morisset	*Dillwyinia* spp.	*C. gummifera*	*C. eximia*
Buladelah	*E. siderophloia/ E. paniculata*	*E. acmenoides*	*C. maculata*
Taree	*E. siderophloia/ E. paniculata*	*E. acmenoides*	*E. punctata/ E. propinqua*
Wauchope	*E. siderophloia/ E. paniculata*	*E. pilularis*	*E. acmenoides*
Kempsey	*E. siderophloia/ E. paniculata*	*C. maculata*	*E. acmenoides*
North Coast:			
Urunga	*E. siderophloia*	*E. acmenoides*	*C. variegata*
Dorrigo	*Lophostemon confertus*	*E. siderophloia*	*C. variegata*
Grafton	*E. siderophloia*	*L. confertus*	*C. variegata*
Casino	*E. siderophloia*	*C. variegata*	*E. tereticornis*
Urbenville	*E. siderophloia*	*L. confertus*	*E. moluccana*
Glen Innes	*L. confertus*	*E. siderophloia*	*E. andrewsii*

Floral rewards and flowering phenology of melliferous flora: The relative values as stated by beekeepers in the surveys for honey yields, pollen, time of year flowering occurred, length of time buds were carried and the years between flowering events for the species of major importance mentioned first in the various studies or mentioned in more than two Forest districts from Table 5.2 is provided in Table 5.3.

Table 5.3 Comments on the level of importance for honey and pollen including flowering phenology for the primary melliferous flora within NSW State forests

Species	Level of honey importance	Level of pollen importance	Time of year flowering occurs	Number of months buds carried for	Years between flowering
Banksia ericifolia	Med-High	High	May-Aug	3-4	Annual
Corymbia maculata	High	High	Apr-Sep	18-20	4
C. trachyphloia	High	High	Feb-Apr	3-4	2
C. variegata	Med-High	High	Jan-Mar	20-24	3-5
Dillwynia spp.	Low	High	Aug-Oct	-	Annual
Eucalyptus acmenoides	Med	Med-High	Oct-Dec	8-9	1-3
E. camaldulensis	High	High	Dec-Jan	12	2-4
E. crebra	High	Med-High	Oct-Dec	6-12	2-3
E. delegatensis	Med-High	High	Jan-Mar	12	2
E. largiflorens	High	Low-Med	Jan-Mar	12	2
E. macrorhyncha	Med-High	High	Feb-Mar	15-24	3-4
E. melanophloia	High	Med	Dec-Jan	1½-2	3-5
E. muelleriana	High	High	Dec-Mar	18-24	3-5
E. paniculata	High	Nil	Nov-Jan	5-9	3-5
E. pauciflora	Med-High	Med-High	Nov-Feb	9-12	2-3
E. siderophloia	High	Nil	Nov-Jan	6-10	1-3
E. sideroxylon	Med-High	Nil	Apr-Sep	4	2-3
Lophostemon confertus	High	Med-High	Dec-Jan	1½	2-4

Nearly all the floral species identified by beekeepers within the most frequently mentioned group had a high or medium to high rating for honey which was probably the main criteria on which beekeepers have selected these species. The values for pollen on the other hand ranged from nil to high with only 50% of the primary floral species rating a high value.

The number of months flowering occurred for each species ranged from a two month period for *E. camaldulensis*, *E. macrorhyncha*, *E. melanophloia* and *Lopostemon* *confertus* to a six month period for *C. maculata* and *E. sideroxylon*. Both the species with the longest flowering period were winter flowering, whereas the species with the shortest flowering periods were primarily summer flowering. Ten (56%) of the listed species had a three month flowering period.

The length of time beekeepers observed each species in bud ranged from one and half months to two years. The Spotted gums (*C. maculata* and *C. variegata*) and two stringybarks (*E. macrohyncha* and *E. muelleriana*) carried buds for close to two years. Five species carried buds for approximately 12 months. The two Grey ironbarks *(E. paniculata* and *E. siderophloia)* carried buds for nine to ten months and five species carried buds from one to four months.

Years between flowering events ranged from annual for the shrub *Banksia ericifolia* and *Dillwynia* spp., up to five years for *C. variegata*, *E. melanophloia*, *E. muelleriana* and *E. paniculata*. The majority of the species ranged from two to four years between flowering events.

Indicative honey yields by floral species: The honey yields varied significantly between species and within each species. Yields of honey in kilograms per hive for the most frequently mentioned species in each forestry district are provided in Table 5.4. There were no honey yields recorded against *Dillwynia* spp. *Banksia ericifolia* and *E. largiflorens* had the lowest average honey yield per hive of 20 kg compared to *Lophostemon confertus* with the highest of 80 kg per hive, closely followed by *E. siderophloia* with 75 kg per hive. The average honey production for all species in Table 5.4 was 45 kg per hive. The species with the greatest range in honey yields included *C. variegata* (14 to 216 kg per hive) and *E. melanophloia* (50 to 135 kg per hive). The minimum yields for all species except *E. melanophloia* ranged from 5 to 27 kg per hive and nine species (50%) had a high range exceeding 100 kg per hive.

Table 5.4 The average and range of honey produced per hive from the primary melliferous species within the State forests of NSW

Species	Average honey yield per hive (kg)	Range (kg)
Banksia ericifolia	20	5-40
Corymbia maculata	50	27-103
C. trachyphloia	50	40-100
C. variegata	55	14-216
Eucalyptus acmenoides	35	14-54
E. camaldulensis	40	27-135
E. crebra	30	15-108
E. delegatensis	40	20-60
E. largiflorens	20	10-30
E. macrorhyncha	50	15-108
E. melanophloia	60	50-135
E. muelleriana	40	10-80
E. paniculata	64	27-104
E. pauciflora	30	20-50
E. siderophloia	75	14-200
E. sideroxylon	30	14-93
Lophostemon confertus	80	27-135

Responses to survey questions – section 2

History of usage: The number of years beekeepers have utilised forestry sites for the placement of hives on a periodic basis varied from those with recently acquired permits to families who have had access to sites for two generations. Forty years was mentioned by a number of beekeepers.

Forestry practices: Responses indicated that beekeeping was generally compatible with forestry management activities, as there was a general acknowledgment that road access and old logging dumps associated with tree harvesting offered beekeepers an excellent road network and suitable apiary locations. The main concern identified by beekeepers was that many tree species required a considerable period of growth before reliable quantities of nectar were produced. Even though some eucalypt species flowered as small trees, they were not regarded as reliable in relation to nectar secretion and thus honey production until more mature. Logging mature species of important nectar and pollen producing trees was regarded as detracting from the value of any given site for beekeeping purposes.

Apiary sites in and adjacent to State forests: The study surveyed beekeepers with beekeeping occupation permits issued by NSW State Forests, even so, this did not necessarily collect information from all beekeepers managing honey bees foraging in State forests. As honey bees are capable of flying two to four kilometres given favourable climatic conditions, it was possible that apiaries placed on private property or other land tenures adjacent to State forests were effectively harvesting this nectar and pollen resource. Table 5.5 provides an indication of the number of apiary sites adjacent to State forests where field honey bees would be able to forage on the floral resources within the State forests.

Table 5.5 Number of apiary sites in and adjacent to State forests, responses from beekeepers.

State forest district	State forest sites	Private property
South Coast:		
Eden/Bombala	33 (57%)	25 (43%)
Narooma	209 (78%)	60 (22%)
Batemans Bay	No data	No data
Nowra	No data	No data
Tablelands:		
Tumut / Tumbarumba	117 (54%)	98 (46%)
Queanbeyan / Badja	No data	No data
Bathurst / Oberon	58 (57%)	43 (43%)
Inverell	78 (58%)	59 (42%)
Western Region:		
Central Murray	No data	No data
Dubbo	130 (85%)	22 (15%)
Mildura	51 (62%)	31 (38%)
Narrandera	77 (58%)	46 (34%) RLPB 11
Baradine (Pilliga)	No data	No data

State forest district	State forest sites	Private property
Forbes	63 (45%)	71 (51%) RLPB 5
Central Coast:		
Buladelah	50 (77%)	15 (23%)
Morisset	20 (65%)	11 (35%)
Taree	42 (60%)	28 (40%)
Wauchope	90 (64%)	50 (26%)
Kempsey	109 (67%)	54 (33%)
Walcha / Gloucester	35 (43%)	48 (57%) RLPB 2
North Coast:		
Dorrigo	74 (95%)	4 (5%)
Grafton	346 (66%)	180 (34%)
Urunga	90 (72%)	35 (28%)
Casino	233 (57%)	176 (43%)
Urbenville	48 (75%)	16 (25%)
Glen Innes	167 (77%)	50 (23%)
RLPB—Rural Lands Protection Board (Travelling stock reserves)		

The number of sites on private property adjacent to State forests was above 20% of the total number of sites available within and adjacent to State forests in all districts except Dorrigo and Dubbo. The average percentage of sites adjacent to State forests was 34% expressed as a fraction of the total number of sites utilizing State Forest flora. No data was collected for five districts as this question was not asked in earlier surveys.

Changed flowering or yielding patterns of forest flora: Observed changes in flowering patterns were interpreted in the following way:

- Drought affected flowering regularity by reducing growth and bud formation
- The age of the trees was said to impact on the potential for honey production from various sites; older trees were considered more reliable;
- The lack of regular flooding, specifically the forests dominated by *E. camaldulensis* in the Riverina were said to have reduced growth and bud initiation, thus reducing the honey yields produced from this once reliable species;
- Fire, either as wildfire or as a deliberate forestry management practice, reduced the value of the areas affected for beekeeping. *Banksia ericifolia*, the most important

floral species identified in the Nowra forestry district, was reported by beekeepers to be of no value for seven years after a fire, presumably due to the time required for this species to regenerate and mature.

How the forests relate to beekeepers calendar of activities: The frequency with which forests were utilised by beekeepers varied according to the distances beekeepers travelled and the reliability of the flora as a source for nectar and pollen. Thus responses varied considerably, indicating some sites were only used every three or four years, whereas other sites were utilised for two or three floral species within the one year. The closer the forest to the beekeepers base, the greater the utilisation by the beekeeper. Forests located further away from the beekeepers base tended to be mainly visited for major flowering events when the species in question had a high probability of yielding a significant volume of nectar and possibly pollen.

DISCUSSION

Survey statistics and beekeeper analysis

The percentage of surveys returned (70–80%) was considered excellent for such an exercise, given that a 25% to 35% response is common place when conducting general surveys. Given this response, the validity of the data collected is strengthened as a result of the high rates of surveys returned. The high percentage (90%) of occupation permits held by commercial beekeeping operations suggest that the forest flora as managed by NSW State Forests is of major importance to this sector, more so than amateur or part time beekeepers.

Responses to survey questions – section 1

The primary melliferous flora by forestry district: The major nectar and pollen producing flora identified by beekeepers within the State forests of NSW was arguably a combination of the frequency of mention within each district study, and the number of sites accessed for each species. Each geographic zone had a number of recurring floral species across districts, indicating a more reliable flowering behaviour or a greater geographic spread than other melliferous flora. The South Coast of NSW had a number of reoccurring species of importance, including *Corymbia maculata, Eucalyptus muelleriana* and *E. longifolia.* The most important Central Coast species included

E. acmenoidies, *E. paniculata* and *E. siderophloia*, whereas the most important species on the North Coast included two species of importance from the Central Coast as well as *C. variegata* and *Lophostemon confertus*.. The tableland's forests were not as extensively utilised by beekeepers as coastal forests, with only a few studies covering the Southern, Central and Northern Tablelands. It was not possible to provide a strong indication of the species of value across these areas although *E. viminalis* and *E. pauciflora* were mentioned in more than one district.

The western districts were characterised by either large river systems prone to periodic flooding, or large areas experiencing long periods of dry weather. Forests were mainly contained either along these river systems, or occupying ridges with skeletal soils or areas of poorer sandy soils. Historically these were of little or no value for grazing, thus escaping the clearing activity associated with early agricultural practice. The primary species of importance along the western river systems was *E. camaldulensis*, with the ironbarks *E. beyeri, E. crebra, E. fibrosa, E. sideroxylon* and the box species *E. melliodora, E. largiflorens* of major importance in the dryer locations across the western districts of NSW.

The results only list the major species of importance to beekeeping interests. The full value of the various forests to beekeepers has not been ascertained, as there are likely to be many minor floral species known to individual beekeepers that when the opportunity presents would be of significant benefit to honey bees from time to time. The value of floral species from which honey bees collect pollen did not receive much prominence in the survey data.

Floral rewards and flowering phenology of melliferous flora: All the primary species identified by beekeepers in the study were given a high or medium-high rating for honey, based on their importance as significant producers of nectar. This would appear to be the main criteria for beekeepers listing the floral species of primary importance in the surveys. Beekeepers regarded the ironbark group of eucalypts as a very important source of nectar in nearly all regions of NSW, including *E. paniculata* and *E. siderophloia* on the coast and those species already mentioned in the western districts. Lack of available pollen, particularly from the ironbark group of eucalypts, would create serious management problems for beekeepers who would have to balance nutritional deficiencies with artificial pollen supplements. Alternatively they would need to ensure colonies were placed on a flowering event that produced surplus pollen prior to the ironbark flowering, or choose sites with other species flowering at the same time as the ironbarks that would provide the pollen required to satisfy honey bee nutritional requirements.

As a source of pollen the floral species mentioned most frequently varied significantly from a nil value to high. Given that an adequate supply of nutritious pollen is required for a honey bee colony to survive and maintain populations capable of harvesting surplus nectar (Kleinschmidt and Kondos 1976, 1977), it seemed to be regarded as secondary in the list of primary species of importance as stated by beekeepers. The importance and role of species that provided quantities of nutritious pollen was not strongly apparent from the results, but pollen must be considered equally as important in the profitable management of hives as compared to nectar producing species. For example, beekeepers on the North Coast favoured *E. siderophloia* for honey production from which honey bees did not collect any pollen. *Eucalyptus acmenodies* flowered during a similar period in the same forests, although not highly regarded for honey production by beekeepers it was valued as a source of pollen, ensuring that the colonies continued to breed and remain in a healthy state (Clemson 1985).

The common name provided by beekeepers for Grey ironbark was split botanically into *E. paniculata* or *E. siderophloia* with differing geographic boundaries. The first species occured on the South Coast, extending into the Central Coast. The second species had a distribution from the Hawkesbury River to the Queensland border. Both had the same flowering period from November to January. The only difference between these species was the years between flowering events with the North Coast species flowering more frequently than the South Coast species. This difference could be rainfall influenced.

The range in the periods for which buds where carried for each species prior to flowering was probably a factor of beekeeper observation dates rather than when each species initiated buds. Many of the melliferous species mentioned by beekeepers were forest trees with buds forming high in the canopy, making them difficult to observe until they had significantly grown in size. The species carrying buds for longer periods allowed beekeepers a greater length of time to plan management activities necessary to prepare colonies for these flowering events. Species with shorter budding periods could be anticipated by beekeepers but not confirmed to be budded until closer to the flowering period, necessitating some forward management predictions by beekeepers.

The surveys indicated that flowering periods do not always occur on a regular three or four year cycle, eg. there may be regular flowering events every second year for an eight or ten year period, then drought or some other factor may interrupt the flowering cycle and the species may not initiate buds for three or four years.

Indicative honey yield by floral species: The information collected provided an indication of the volume of nectar capable of being produced by each species if the conditions were favourable. The expected yields of honey reported by beekeepers possibly reflected the better years in which these floral resources were utilised. The low yields of honey per hive for any given species provided evidence that beekeepers should not always rely on the flora identified to consistently be relied upon to produce large surpluses of nectar.

Future studies should reveal what circumstances favour higher nectar production for each species. Beekeepers may be able to provide further information on this subject by indicating what years produced larger crops of honey from the same species, matching these records with rainfall data over time. The two species that produced the largest average honey yield per hive, *E. siderophloia* and *Lophostemon confertus*, were also species occurring on the North Coast of NSW in which the highest annual rainfall in the State occurred. This indicates a possible relationship between available moisture and ultimately honey production by beekeepers.

Response to survey questions – section 2

History of usage: Beekeeping in NSW State forests was not a recent phenomena. Responses and comments from beekeepers indicating two generational periods of use of some apiary sites suggested a significant knowledge of the flora around these sites. Years of observations and experiences in the management of honey bees under varying circumstances would suggest that the knowledge gained by some individuals would be extensive. Although not completely scientifically accurate, it may be the only information available on the flowering characteristics of many melliferous species.

Forestry practices: The major reason why beekeepers utilised State forests to the extent they did was due to the extensive well maintained road network and the availability of small cleared areas periodically located along these roads that were suitable for the placement of hives. Yet the reason why many of these roads existed was primarily for log extraction associated with the harvesting of mature trees which beekeepers indicated where the more reliable in relation to nectar secretion. Whether this was the case for all species or only some of the key species targeted by beekeepers was not made clear. This question offers further possibilities for future research to ascertain the volume of nectar and duration nectar is available from species of differing age groups.

Even though fire was mentioned as a potentially damaging event interrupting flowering frequency of the various species, it would be more likely that a low intensity managed fire would have less of an impact on the flowering frequency of trees than a high intensity fire that would be expected to seriously interrupt the growth and flowering of trees for many years. The main comments on fire arose concerning *Banksia ericifolia.* This species rejuvenates after fire very readily and can be said to be well adapted for such events. Even so, the regularity of fire events even low intensity, was observed to have a significant impact on nectar and pollen availability over time. Perhaps this species and the floral community in which it grows could be managed in relation to purpose lit fires with consideration for the flowering frequency of this species. This could also be expected to benefit many indigenous nectarivorous fauna and invertebrates known to be attracted to this species when in flower.

Apiary sites in and adjacent to State forests: The number of sites adjacent to State forests where honey bees can utilise State Forest flora varied significantly from district to district. This probably depended on the size of the individual forests and accessibility to private property. The proportion of private property sites adjacent to State forests was greater on the tablelands and western forested lands (except Dubbo) than on the coastal forests, reflecting the relative ease of access and the smaller size "island" forests in inland NSW. Thus there could be many beekeepers that choose to use private property adjacent to State forests for the purpose of being able to access the flora within the State forests. These beekeepers were not able to be contacted for the surveys. The value of State forests to the NSW beekeeping industry is likely to be greater than the results and permit numbers indicate.

Changed flowering or yielding patterns of forest flora: The question remains: what triggers bud initiation, flowering regularity and eventually nectar and pollen yields of individual species? Given the extensive knowledge possessed by beekeepers on melliferous flora, the opportunity presents itself to record trends in flowering patterns and possibly to suggest reasons influencing these trends. Drought was a logical influence on the cycle of any plant and, as such, is beyond the influence of local district forest managers or even State policy determination. The age distribution of the floral species was said to impact on its relative reliability to yield nectar and flower for a prolonged period. This aspect could potentially be influenced at a local forest management level. This possibility requires further investigation as some species may be more beneficial to the economy over time from the harvest of nectar rather than the removal of logs. Some of the slower growing species, particularly the ironbarks such as *E. sideroxlyon*, should be considered candidates for such studies. Thinning regrowth forests which allows the remaining trees increased access to soil moisture and nutrients, may benefit beekeepers by providing the opportunity for trees to mature more rapidly and increase the frequency of flowering and/or yield greater volumes of nectar.

The lack of regular flooding as a reason why flowering frequency and reliability have diminished was mainly directed at *E. camaldulensis.* There could also be other confounding issues such as rising salt levels or increasing insect pressure on the remaining trees. Whatever the reason, sufficient comments were received for this observation to be of concern as the general health of the whole *E. camaldulensis* forest type may be compromised if flowering and subsequent seed production is affected over a wide area of western NSW.

How the forests relate to beekeeping calendar of activities: It was apparent that access to the flora occurring within State forests was important during certain times of the year with a yearly variation depending on the choice of flowering events within each beekeepers operational range. The results indicated that the forests were mainly utilised for the harvest of surplus nectar. They did not indicate that the forests' primary use was to stimulate honey bee colonies to expand populations, by seeking floral conditions that provided pollen attractive to honey bees and a light nectar flow. These conditions are extremely important to the management of commercial honey bees but there is no immediate income derived from such activities. Thus beekeepers may have under estimated the value the forests. Their comments focussed instead on the direct economic return derived from honey extraction rather than the conditions necessary to manage hives to produce these honey crops, i.e. seeking suitable breeding conditions prior to the flowering of major nectar yielding species.

CHAPTER 6

BULK HONEY DELIVERIES FROM BEEKEEPERS TO CAPILANO HONEY LIMITED

INTRODUCTION

The previous two chapters (Chapters 4 and 5) document the primary floral resources of New South Wales (NSW) determined by surveying the whole commercial beekeeping industry, then one group specific to the use of sites within the State forests of NSW. Both are anecdotal in as much as they are the beekeepers response to a question, asking them to place a value on honey production and the nutrient values of pollens.

This chapter provides specific data on the precise volume of honey delivered to Australia's largest honey packer by NSW based commercial beekeepers. The volume of honey per species over an eight year time period will indicate which were the primary floral species of importance to the NSW beekeeping industry directly related to honey production.

Once honey bees have harvested nectar and it has been ripened and stored in the supers, the beekeepers will, in most circumstances, remove full or near full supers and extract the honey. Occasionally supers full of ripened honey may be left on a hive when the colony is entering a period of limited fresh nectar availability. Once the honey is extracted it is most frequently stored in bulk containers for ease of transport to a business specialising in the packing of retail honey. A minority of commercial beekeepers pack their own honey, by far the majority are pure primary producers and do not enter the manufacturing business.

Most honey is traded by beekeepers and sold usually by long term arrangement with one of a number of companies that process and pack honey for the retail trade. Capilano Honey Limited is one such honey packing company that regularly purchases bulk honey from NSW beekeepers. Of the honey packing companies purchasing NSW bulk honey, only Capilano, at the time of this study, possessed records which identified the floral source of the honey purchased by them. The most important aspect of the

Capilano honey data provided in this chapter is that this company was estimated to handle up to 70% of Australia's honey production (Bill Winner 1997, pers com. Beekeeper Services Manager, Capilano Honey Ltd., Queensland). A set of data in relation to bulk honey deliveries as identified by a floral source that can be attributed to a large sample of the NSW commercial beekeeping industry, will prove valuable in determining the primary floral species of importance to beekeeping in NSW and provide supporting evidence for Chapters 4 and 5.

MATERIALS AND METHODS

Bulk honey was delivered to Capilano Honey during business hours throughout the year. The data set provided relates to honey deliveries between 1989 and 1996 inclusive. The 1989 and 1990 data was incomplete, as the company were not at the time recording all the floral sources of the honey received from beekeepers.

Beekeepers, when delivering bulk honey to Capilano, were asked to identify the floral source of the honey. The naming of the honey type by the beekeeper delivering the honey was the best estimate of the source of honey by each individual beekeeper. Some examples of entries included Red gum, River gum, River red gum, Red gum mix, coastal. Where a beekeeper named the batch of honey delivered as, for example, Yellow box mix, half the weight was allocated to Yellow box and the other half was not allocated to any species.

The common names used by beekeepers to describe the floral source of the honey, in some instances, referred to a number of possible floral species. Large volumes of honey were named according to the bark type of the eucalypt from which the honey was derived, e.g., Stringybark. Where a common name was normally used to refer to a single species, the species was identified. Three references, Blake and Roff (1988), Clemson (1985), and Somerville (1999a), were used to assist in the matching of the common name and botanical name of the floral species. Advice on floral sources of honey was sought from industry experts, John Rhodes (Apiary Officer, NSW Agriculture Tamworth) and Bill Winner (Beekeeper Services Manager, Capilano Honey Ltd., Queensland).

RESULTS

The total amount of honey receipts recorded varied from 2,470,752 kg in 1989 to 10,758,231 kg in 1993, (Table 6.1). Most of this honey was able to be attributed to a floral species. From 1989 to 1991 over 20% of the recorded honey delivery could not be attributed to any floral species. From 1992 to 1996, this ratio of unidentified species was reduced to approximately 10% of the total recorded volume of honey delivered.

Table 6.1 Capilano Honey Limited receipts from NSW suppliers from 1989 to 1996.

Year	Total kg	Percentage of total with no common floral source name provided
1989	2,470,752	23.6
1990	2,494,320	24.6
1991	9,779,045	20.1
1992	7,909,543	9.3
1993	10,758,231	8.7
1994	8,774,843	10.6
1995	7,879,290	12.4
1996	9,657,616	10.6

The data provided in the following Tables 6.2, 6.3 and 6.4 relates to the honey delivered that could be attributed to an identifiable floral source. Not all common names used by beekeepers were able to be identified as a species and thus given a botanical name. Where this is the case, "species unknown" has been used, with the common name in brackets.

The eucalypts and related species comprise the most important sources of honey, whereas the single most importance species was *Echium plantagineum*. Over the eight year period eucalypts and related species contributed 69% of the total identifiable sources of honey. *Echium plantagineum* contributed 20% of the honey for the same period. There were no records for *Echium plantagineum* in 1989 and 1990. The range from 1991 to 1996 for this species consisted of 9.6% in 1994 to 29.7% in 1996 as a ratio of the total honey delivered. The primary floral species for which 100,000 kg of honey or greater was delivered to Capilano are listed in Tables 6.2 and 6.3.

As eucalypts and their related species were identified as the most important genus, data for these species has been kept separate to aid the reader in identifying both groups. A total of 28 *Eucalyptus* and *Corymbia* species are listed in Table 6.2. There is a strong probability that Mahogany refers to *E. acmenoides*. It was not however that clear what species "Apple" belonged to. Two likely species could have been *Angophora floribunda* or *E. bridgesiana*. If any honey from this unconfirmed source was attributed to *E. bridgesiana*, then this species would have certainly been listed in Table 6.2. Due to the use of the same common name for different species, it was not possible to differentiate between *C. maculata/C. variegata* (Spotted gum), *E. paniculata/E. siderophloia* (Grey ironbark) and *E. punctata/ E. propinqua* (Grey gum).

Table 6.2 **Honey deliveries to Capilano Honey Limited (NSW suppliers). *Eucalyptus* and *Corymbia* species with honey delivered exceeding 100,000 kg, in order of the total honey delivered from 1989 to 1996.**

Species	1989	1990	1991	1992	1993	1994	1995	1996	Total
E. melliodora	141,785	354,471	866,759	402,333	1,307,512	257,134	176,907	383,304	3,890,205
E. ochrophloia	90,892	130,202	884,757	348,042	114,704	403,971	1,131,421	396,655	3,500,644
E. albens	58,222	26,690	316,458	114,030	955,770	501,363	34,292	914,131	2,920,956
C. maculata, *C. variegata*	213,014	6,272	82,084	103,831	*	1,369,659	203,979	7,655	1,986,494
E. paniculata, *E. siderophloia*	71,694	17,657	174,290	214,847	418,568	167,748	239,647	409,176	1,713,627
E. microtheca	13,822	65,414	117,850	131,432	35,246	254,407	14,257	113,133	745,561
E. crebra	121,067	18,742	76,844	110,545	30,860	35,291	5,681	198,743	597,773
E. andrewsii	48,301	30,577	29,122	297,674	32,328	108,687	31,634	7,032	585,355
E. sideroxylon	*	9,156	113,786	61,113	208,702	51,532	9,089	110,441	563,819
E. moluccana	*	11,151	47,089	155,311	191,070	84,247	5,524	1,757	496,149
E. pilularis	85,748	3,602	36,803	61,142	1,192	127,369	138,817	19,048	473,721
E. largiflorens	1,508	*	93,092	56,543	135,351	76,168	56,931	53,734	473,327
E. camaldulensis	29,599	22,527	43,105	106,630	58,702	119,967	50,398	24,734	455,662
E. populnea	*	23,867	122,484	21,216	29,593	40,844	143,547	47,378	428,929
E. melanophloia	267,399	57,007	*	7,762	26,309	297	2,637	19,285	380,696
(Apple/Angophora) Species unknown	*	*	46,112	71,246	29,825	132,377	60,369	37,210	377,139

Table 6.2 cont.

Species	1989	1990	1991	1992	1993	1994	1995	1996	Total
(Mahogany) Species unknown	6,668	5,191	34,186	98,688	51,786	61,351	68,300	45,412	371,582
E. microcarpa	57,216	4,190	3,259	2,673	127,296	44,463	*	67,752	306,849
E. fibrosa	8,021	5,856	209,221	8,483	5,355	*	24,655	14,211	275,802
E. caleyi	*	600	2,675	121,894	24,478	2,923	11,814	70,579	234,963
E. tereticornis	1,456	1,190	11,206	13,468	*	141,595	37,425	7,152	213,492
E. punctata, E. propinqua	2,957	3,250	62,625	30,716	42,128	45,963	5,039	12,968	205,646
E. pauciflora	*	*	10,040	2,356	*	21,334	105,322	1,168	140,220
E. acmenoides	*	*	14,315	14,011	22,623	6,984	15,957	59,038	132,928
E. dealbata	*	1,490	19,580	12,525	20,699	4,438	4,119	40,476	103,327
* No records of honey delivered									

The list of major honey flora that were not eucalypts or related species contains 15 identifiable floral sources of honey (Table 6.3). Of these, nine were introduced species, four of which were considered weeds in the agricultural context, and the remaining five were considered agriculturally important.

The volume of honey delivered from the "weed" *Echium plantagineum* exceeded all other species, including eucalypts and related species, by over double the amount of honey delivered over the eight year period — 8,278,971 kg compared to the next most significant species *Eucalyptus melliodora* 3,890,205 kg.

Table 6.3 Honey deliveries to Capilano Honey Limited (NSW suppliers). Main non-eucalypt or related species by weight (kg) by honey delivered exceeding 100,000 kg in order of the total honey delivered from 1989 to 1996.

Species	1989	1990	1991	1992	1993	1994	1995	1996	Total
Echium plantagineum	288	*	1,510,532	187,703	1,938,685	839,030	932,612	2,870,121	8,278,971
Lophostemon confertus	35,686	202,143	301,881	106,388	335,893	42,683	221,919	73,524	1,320,117
Brassica napus	*	26,122	154,021	296,754	160,819	15,930	146,035	135,396	935,077
Trifolium repens	52,294	134,915	2,680	26,861	249,494	30,271	58,057	195,891	750,463
Species unknown (Thistle)	15,607	45,203	23,209	74,973	226,830	95,807	6,269	218,817	706,715
Banksia ericifolia	19,136	24,273	40,121	57,546	64,022	95,572	95,581	130,209	526,460
Guioa semiglauca	40,345	14,648	74,834	65,926	47,498	54,466	85,083	52,623	435,423
Melaleuca quinquenervia	11,809	9,515	61,519	27,209	73,170	44,162	69,314	126,639	423,337
Medicago sativa	4,656	13,117	43,650	19,646	75,258	9,178	55,674	53,260	274,439
Echium vulgare	*	*	5,896	114,696	47,919	1,172	13,364	46,235	229,282
Leptospermum flauescens	877	80,831	6,524	62,101	4,682	7,824	30,687	12,850	206,376
Citrus spp.	*	*	41,393	6,038	43,107	32,852	40,642	5,608	176,938
Centaurea solstitialia	*	1,759	12,881	35,237	77,091	17,725	591	31,654	176,938
Alphitonia excelsa	*	*	13,289	101,558	1,788	2,768	2,670	8,841	130,914
Helianthus annuus	*	*	23,205	49,785	*	3,813	17,845	15,442	110,090
*No records stated									

Floral species contributing less than 100,000 kg over the eight years in alphabetical order included: *Aegiceras corniculatum* 9,141; *Arctotheca calendula* 33,376; *Eremophila sturtii* 22,035; *Eucalyptus bridgesiana* 90,565; *E. dumosa* 5,590; *E. fibrosa* subsp. *nubila* 82,486; *E. grandis* 25,229; *E. incrassata* 18,522; *E. leucoxylon* 754; *E. oleosa* 16,853; *E. pilligaensis* 95,100; *E. polyanthemos* 12,152; *E. porosa* 2,645; *E. rubida* 96,424; *E. signata* 35,221; *E. socialis* 2,442; *E. viminalis* 3,716; *Eucalyptus* spp. (Peppermint) 95,253; *Eucryphia moorei* 85,331; *Fagopyrum esculentum* 793; *Heliotropium amplexicaule* 90,536; *Hypochoeris radicata* 19,045; *Lophostemon sauvelolens* 10,320; *Macadamia* spp. 47,502; *Muehlenbeckia cunninghamii* 13,247; *Pittosporum undulatum* 2,060; *Rapistrum rugosum* 70,807; *Saccharum officinarum* 18,028; *Salvia reflexa* 2,056; Species unknown (Ash) 18,174; Species unknown (Carpet weed) 10,284; Species unknown (Pink gum) 7,774; Species unknown (Silver myrtle) 1,183; *Syncarpia glomulifera* 18,395; *Vicia sativa* 3,969.

Eucalypts and related species

Clearly the genus eucalypts and its close relatives were the most important sources of honey for NSW beekeepers supplying Capilano. Eucalypts were frequently referred to according to their bark characteristics, such as gum, box, ironbark, etc. Table 6.4 lists the value of each group of eucalypts for honey production according to bark type. Each group contains unidentified species which were stated by beekeepers to be ironbark or box honey, etc. The data attributed to an identifiable species has also been included in Table 6.4, e.g., the data for *E. melliodora* (Yellow box) is a component of the total honey contributed by the box-bark type eucalypts.

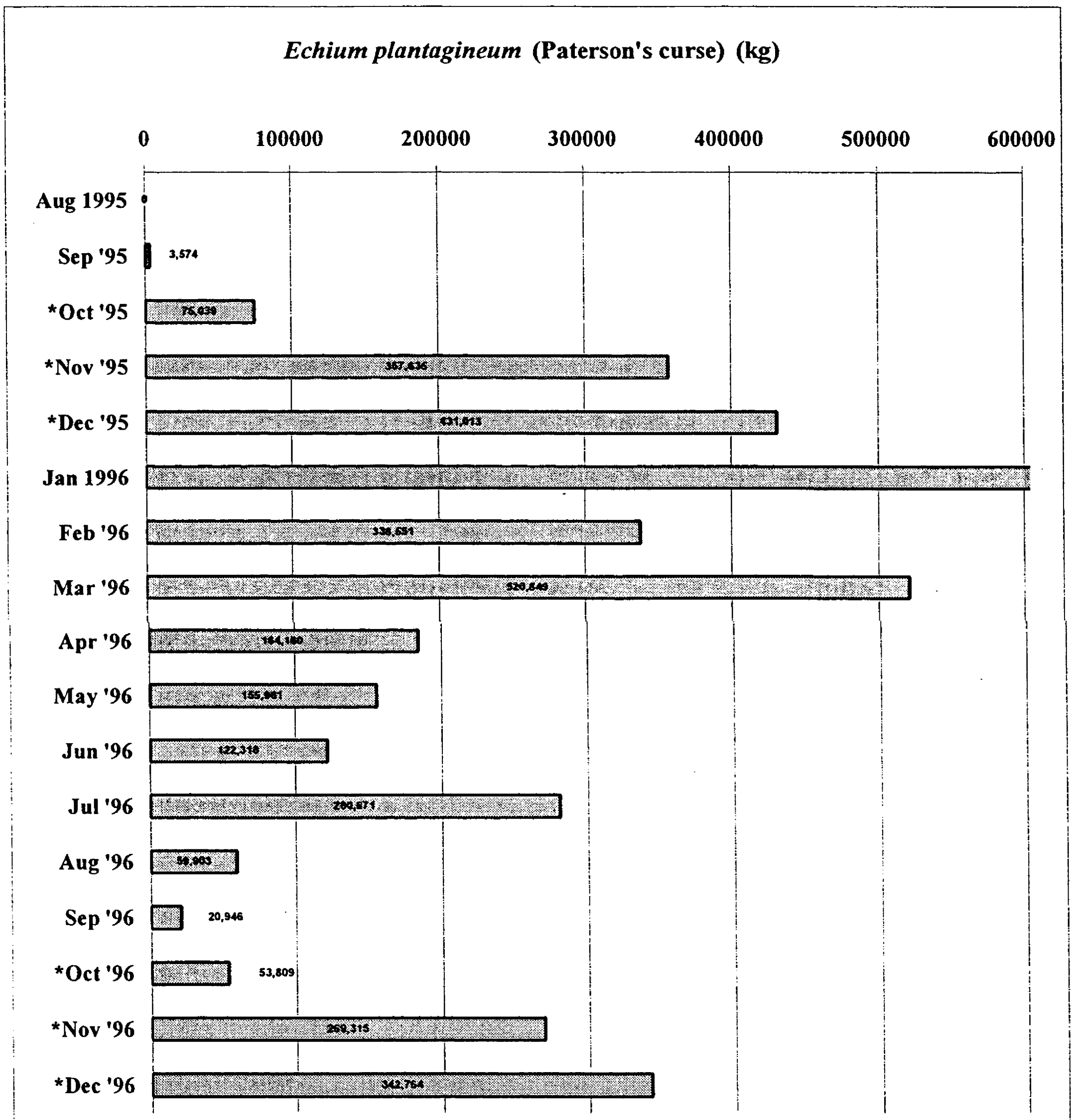
The box and ironbark group of eucalypts far exceed all other bark type groups of eucalypts for honey production by 100%. Both groups are also similar to the volume of honey originating from *Echium plantagineum*.

Table 6.4 Eucalypts and related species described by bark type — Honey receipts by Capilano Honey in kg from 1989 to 1996.

Bark type	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**Total**
Box	301,838	493,023	1,693,045	923,164	2,900,285	1,341,304	444,040	1,672,419	9,769,118
Ironbark	617,435	240,512	1,384,590	1,273,939	2,076,967	835,822	767,955	1,702,982	8,900,202
Ash	224,941	164,381	950,682	706,858	148,224	640,027	1,301,872	422,735	4,559,720
Gum	288,111	106,736	394,685	334,741	253,957	1,936,949	486,467	224,786	4,026,432
Stringybark	176,890	222,996	711,544	143,628	371,324	465,199	1,457,295	132,982	3,681,855
Mallee	12,677	2,401	42,172	340,440	293,503	530,069	87,532	67,665	1,376,461
Bloodwood	50,470	30,867	172,249	56,239	173,924	509,738	98,664	63,363	1,155,514
Mahogany	6,668	5,191	48,501	112,699	74,409	58,335	84,257	104,450	494,510
Peppermint	0	0	1,188	16,708	1,793	38,013	30,777	6774	95,253

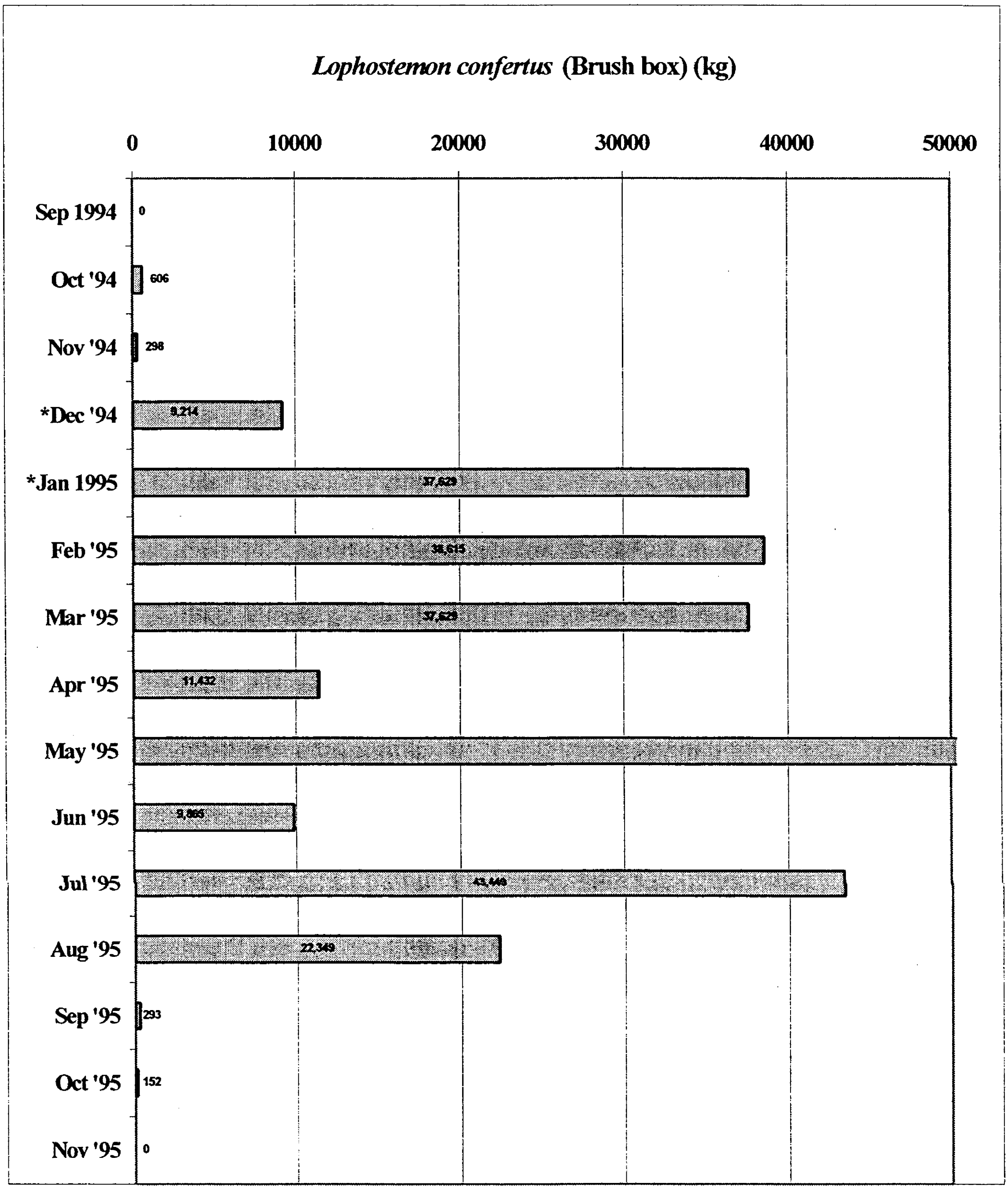
Honey receipt month

The volume of honey received per species is the most meaningful information from the data provided. Even though records were obtained indicating the monthly delivery dates for each batch of honey, relevance to immediate past flowering events was not always the case.



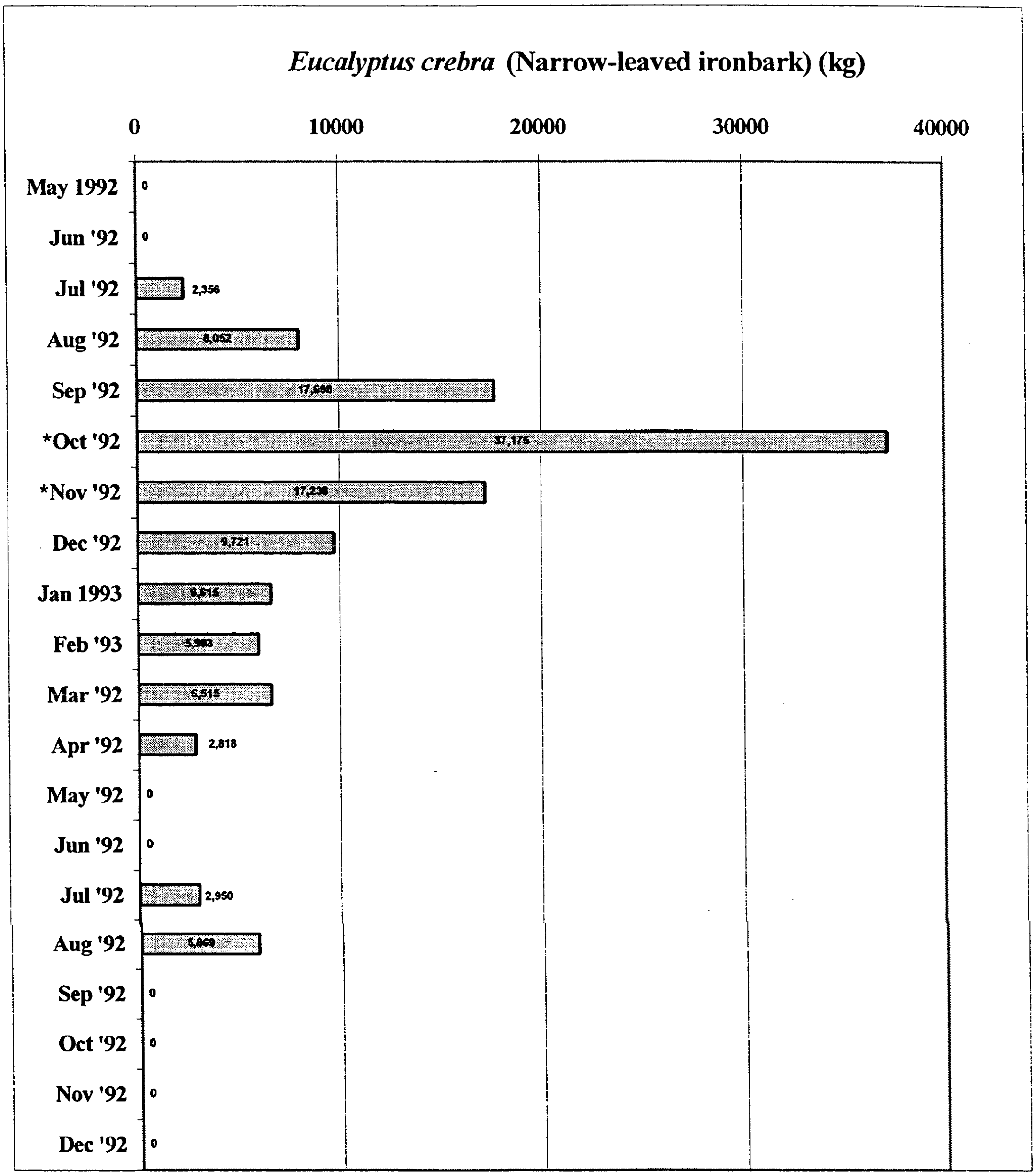
* Main flowering period (Somerville 1999a)

Figure 6.1 The main flowering period in relation to the time lag in extracting and delivering honey from *Echium plantagineum.*



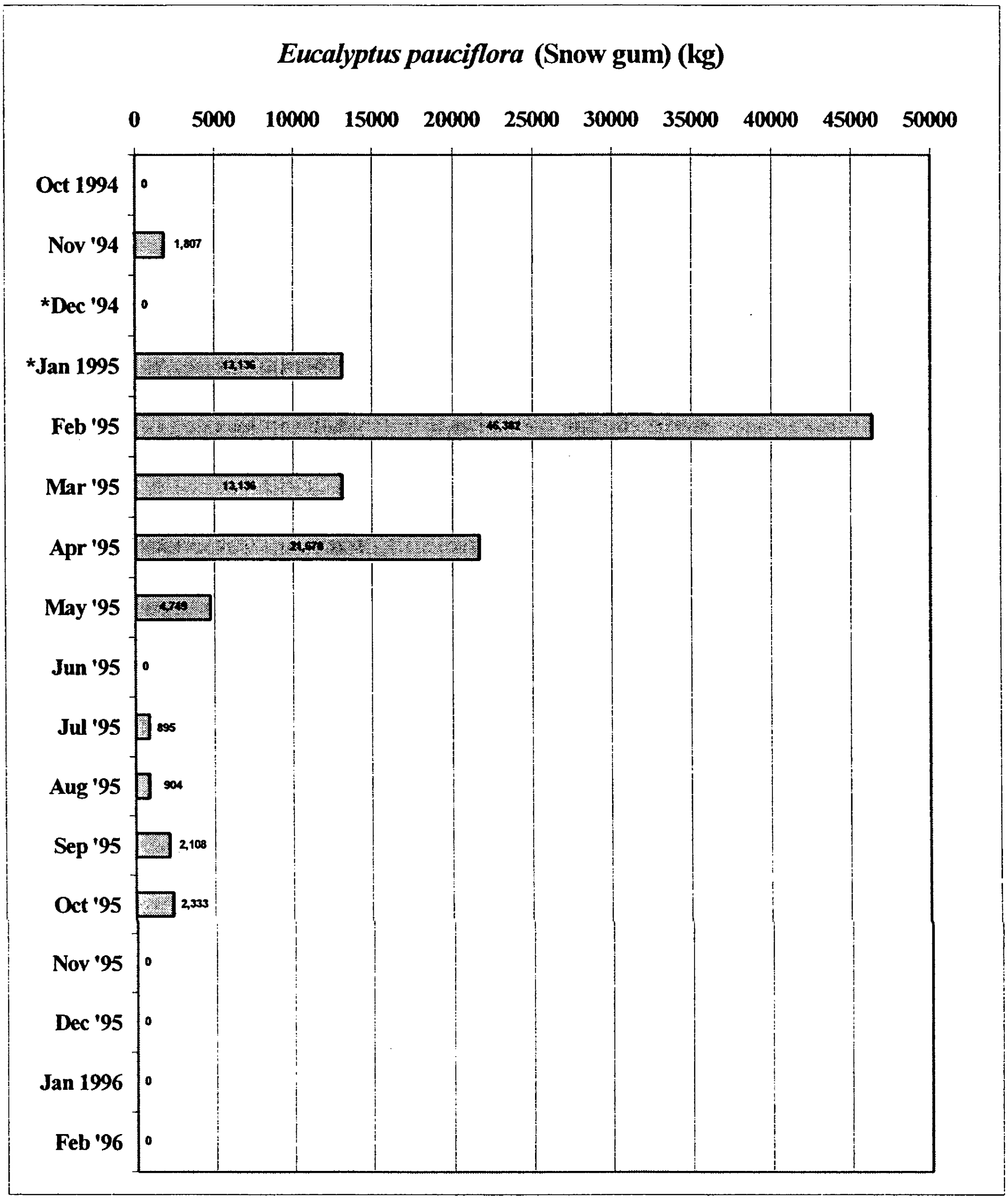
* Main flowering period (Somerville 1999a)

Figure 6.2 The main flowering period in relation to the time lag in extracting and delivering honey from *Lophostemon confertus.*



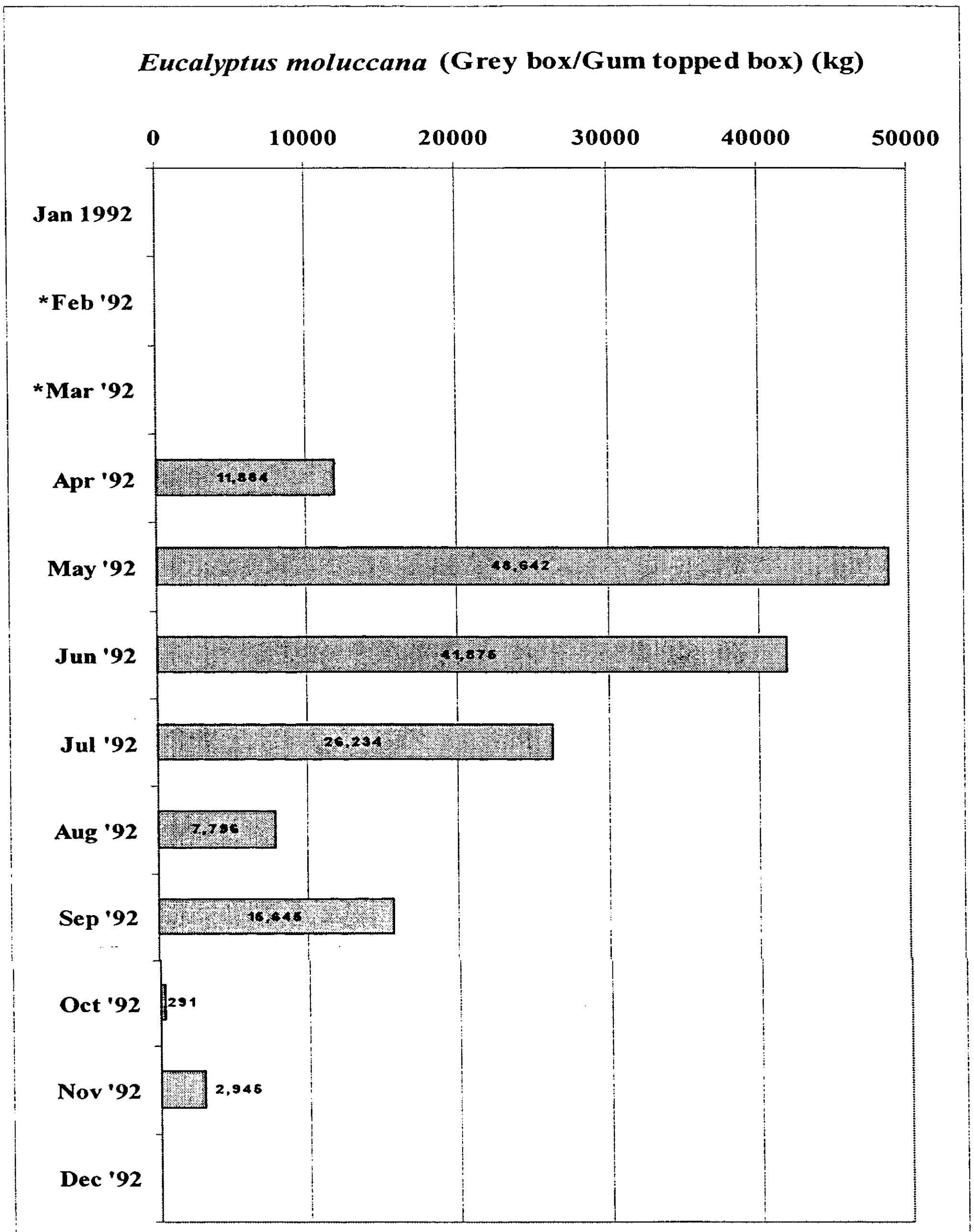
* Main flowering period (Somerville 1999a)

Figure 6.3 The main flowering period in relation to the time lag in extracting and delivering honey from *Eucalyptus crebra*.



* Main flowering period (Somerville 1999a)

Figure 6.4 The main flowering period in relation to the time lag in extracting and delivering honey from *Eucalyptus pauciflora*.



* Main flowering period (Somerville 1999a)

Figure 6.5 The main flowering period in relation to the time lag in extracting and delivering honey from *Eucalyptus moluccana.*

Figures 6.1 to 6.5 illustrate the honey delivery for five floral species associated with a single flowering event. *Echium plantagineum* flowers normally from October to December (Figure 6.1). Most of the honey produced from this species was delivered from November through to March, with small amounts of honey delivered up until the following flowering period 12 months later. Honey delivered in July increased either due to a new honey quota period for individual suppliers or the necessity to hold back honey in the previous financial year for taxation purposes. Thus the dates the honey was delivered did not necessarily indicate the year in which it was produced.

The main flowering period for *Lophostemon confertus* was in December and January (Figure 6.2). A large proportion of the 1994 and 1995 honey from this species was delivered from January to March, with another significant volume delivered in July, similar to the increase in *Echium plantagineum* honey deliveries in the same month. Most honey was delivered within eight months of being produced.

Most of the honey delivered for *Eucalyptus crebra* was during the middle of the normal flowering period (Figure 6.3). The flowering range suggests that blossom may have been available much earlier, however no information was available to verify this possibility. Most honey from this species had been delivered within three to four months of the completion of the normal flowering period.

Honey was also delivered within three to four months of the normal flowering period for *E. pauciflora*. This species is another example of honey being produced in one year (December), and extracted by beekeepers in the following year (January/February). Small volumes of honey from *E. pauciflora* continued to be delivered for nine months after the completion of the flowering period.

The normal flowering period for *E. moluccana* was in February and March, yet the bulk of the honey was delivered from May to July for this species and continued to be delivered for eight months after the flowering period. In this case the honey produced in the autumn period may not have been extracted until early spring. Honey bee colonies require stored honey for winter food. If colonies only consume part of this stored honey over winter then the remainder would be extracted in early spring to allow comb space for the colony to begin its seasonal expansion activities.

In all five floral species, the delivery of honey ranged from three to nine months after the normal flowering period, although the bulk of the honey for each species was delivered within three to four months of the average flowering periods. The period in which the honey was produced in all floral species was significantly different to the months and even the year in which the honey delivery was recorded.

DISCUSSION

Capilano Honey Limited

The records for the eight year period provide an excellent set of data to ascertain the honey production value of a range of various floral species accessed by NSW beekeepers. The records are not complete in the first two years and, in the first three years, over 20% of the honey was not able to be allocated a floral source. Even given these shortcomings, the large number of commercial beekeepers that supplied Capilano and the dominant size of the company in the honey packing and marketing sector of Australia, particularly NSW, provide an assurance that the data related to in excess of 50% of the commercial beekeeping industry in NSW.

Floral source of honey

The clear dominance of *Echium plantagineum* as the main species of importance for honey production supports evidence presented in Chapter 4 in relation to the State survey of commercial beekeepers. On average for the eight year period, *Echium plantagineum's* contribution to the total honey produced by beekeepers supplying honey to Capilano was 20%, which was a very significant volume of honey. The total honey volume contributed by *Echium plantagineum* of 8,278,971 kg for the eight year period far exceeded the next largest volumes of honey, 3,890,205 kg from *Eucalyptus melliodora* and 3,500,644 kg from *E. ochrophloia*, firmly establishing its statewide significance to the beekeeping industry. The monetary value associated with *Echium plantagineum* to the viability of beekeeping businesses in NSW must, as a consequence, be extremely substantial.

The reliability of this species to produce honey each year can be seen to vary significantly. Therefore the percentage of each years' total production attributed to

Echium plantagineum varied as a consequence. This variation in annual honey receipts was probably influenced by the climatic constraints experienced by honey bees and *Echium plantagineum* before and during the flowering event. Drought or dry conditions would be expected to minimise nectar secretion (although it may encourage nectar secretion in the short term), or adverse weather conditions during the flowering period may have restricted the number of foraging flights of honey bees.

Other species of major importance for their honey production contribution to the NSW beekeeping industry with volumes exceeding 1,000,000 kg were *Eucalyptus albens, Corymbia maculata/C. variegata, E. paniculata/E. siderophloia* and *Lophostermon confertus*. *Brassica napus* was just under this figure with 935,077 kg. All these species were rated as the most important floral species contributing to beekeeping in NSW, in Chapter 4, except *E. ochrophloia*. This species has only a limited distribution in NSW in the north west of the State. Most of the habitat for *E. ochrophloia* occurs within Queensland. Thus the predominance of this species in the data associated with NSW beekeepers would be as a result of a large number of hives being transported from NSW into Queensland for that flowering event.

This suggests some caution in interpreting the honey receipt data, as it relates directly to the postal address of the beekeeper and not the location from which honey was harvested. Other species that were listed in the results and may also have their origins within Queensland include *E. fibrosa* subsp. *nubila* (Blue-top ironbark) and *Heliotropium amplexicaule* (Purple top). Unidentified proportions of other species may also be attributed to locations within Queensland.

The most important genus of plants was *Eucalyptus* and its close relative, *Corymbia*, with 69% of the named honey receipts identified as the floral origin. Yet the reliability of this group of plants to produce nectar annually was not as apparent as the group of non *Eucalyptus* or *Corymbia*. Many species of eucalypts had phenomenal honey production in some years with very low yields in others.

The most important eucalypt species, *E. melliodora* had two years (1989 and 1995) when the total honey received by Capilano was below 200,000 kg, compared to 1993 when the honey received was over a million kg. The next most important eucalypt species also demonstrated large fluctuations in honey receipts with three years production below 200,000 kg (1989, 1990 and 1993), compared to 1995 with over a million kg delivered.

The coastal species, *Corymbia maculata/C. variegata* had relatively low honey receipts below or equal to 200,000 kg per year for all years except 1994, when well over a million kg was delivered. The next six most important eucalypt species on the basis of the total honey received for the six years (1991 to 1996) provide evidence of the dramatic differences in nectar harvested from individual floral species by honey bees per year. The Northern Tablelands species *E. albens* experienced two years of poor production with below 200,000 kg, two years were reasonably good with between 300,000 and 500,000 kg, and two years were exceptional with in excess of 900,000 kg delivered. The coastal ironbark *E. paniculata/E. siderophloia* also exhibited a similar pattern, with two years of poor production below 200,000 kg, two years above 200,000 kg and two years of production above 400,000 kg. The next four species, *E. microtheca, E. crebra, E. andrewsii* and *E. sideroxlylon* only recorded one exceptional year of production in six.

The large variation in production between years associated with each floral species was likely to be associated with the time between flowering events. When these species were not available or had a limited flowering event, other floral species would be targeted by beekeepers. The data does not necessarily highlight the regularity of flowering events particularly for floral species that are not as favoured by beekeepers.

The second, third and fourth most important *Eucalyptus* and *Corymbia* species, *E. ochrophloia, E. albens* and *C. maculata/C. variegata* are primarily winter flowering. The choice of floral species on which to place hives anywhere within NSW would be limited at this time of year, thus ensuring that the popularity of these floral species would be heightened as a consequence.

Nearly all the non *Eucalyptus* or *Corymbia* species are likely to have an annual flowering cycle, thus their importance is justifiably associated with their flowering regularity. The North Coast rainforest species *Lophostemon confertus* is in the top ten most important floral species of importance to NSW beekeepers, yet it has been known to have on and off years of production similar to the eucalypts in the same geographic region. The next three species *Brassica napus, Trifolium repens* and thistles (species unknown) all flower regularly each year and are dependent on the soil moisture conditions and weather at the time of flowering to produce abundant nectar.

The oil seed crop *Brassica napus* has become very widespread in the southern cropping areas of NSW and the area available to beekeepers is sufficient not to cause any serious competition between beekeepers for suitable sites. This species also flowers at a time of year (early spring) when colonies are being managed to encourage breeding and population expansion.

The pasture species *Trifolium repens* has a statewide distribution, occurring virtually wherever primary producers have actively cultivated improved pastures. This pasture species has the potential to be of greater importance to beekeepers but the climatic conditions under which it yields nectar are not always met. It is probably a floral species that is considered by beekeepers whenever soil moisture and climatic conditions are favourable.

Thistles, as referred to by beekeepers, may include a number of species, all of which are considered as agricultural weeds, and flower mainly during the summer months. The occasional large crops of honey extracted from this group of plants make them a worthwhile addition to beekeepers' choice of nectar sources. Two years out of the eight, honey deliveries exceeded 200,000 kg, which was a significant volume of honey when compared to other floral species.

Honey receipt month

The data provided by Capilano, although useful in identifying the primary floral source of importance to NSW beekeepers, was not as useful in identifying factors such as the flowering period of the various floral species. The time lapse between honey deliveries after the actual flowering period was, in some cases, over twelve months. A range of reasons may have influenced beekeepers decisions to sell or hold onto bulk honey. These could have included the time after the flowering event the honey was extracted, or economic influences such as tax year considerations and expected price fluctuations.

The bulk honey data does not strongly identify the floral species that produced surplus nectar which was collected by honey bees and ripened, but left on the hives for the purpose of providing food to the colony during lengthy periods of nectar shortage. These circumstances may occur over a winter period when few floral species are in flower or when the climate is not conducive for the honey bees to fly and be active. These factors may also be equally relevant during a long dry period when no flowering events are available or the harsh dry conditions inhibit the flowering species to yield surplus nectar.

CHAPTER 7

CHEMICAL ANALYSIS OF HONEY BEE COLLECTED POLLEN FOR CRUDE PROTEIN, AMINO ACIDS, FAT AND MINERALS

INTRODUCTION

Of the two food substances collected by honey bees, it could be argued that pollen is by far the most important for the general welfare and long term productivity of the colony. Certainly without nectar or access to stored honey a colony would perish in the short term. In the medium term, the same would occur in the absence of pollens, but even with reduced pollen intake, the productivity of a colony is seriously affected. A complete artificial replacement for pollen is not available, it is for nectar. The previous chapters have provided information on the value of melliferous species to beekeepers in NSW for honey production. Chapters 4 and 5 alluded to values of melliferous species as a source of pollen, but this was largely anecdotal. In Chapter 4 beekeepers were asked to provide a rating for pollen for all floral species identified as being of major importance to honey bees. In so doing, this rating may translate to mean a number of possibilities including the abundance of a pollen, time of year the pollen is available, or it has been perceived by beekeepers that the floral source in question produces a highly nutritious pollen superior to other pollen sources available at the same time.

This chapter provides data for bee-collected pollens from mainly southern New South Wales (NSW), which will assist in clarifying the nutritional value of pollen from various melliferous species based on their chemical composition. By so doing, another set of information will be created that will contribute to the previous chapters by providing information on the nutritional quality of pollen.

Honey bees require pollen to satisfy the dietary requirements for protein, minerals, lipids and vitamins (Herbert and Shimanuki 1978). When honey bees are maintained on pollens that are marginal in nutritive value or the quantity of pollen available to the colony is limited, brood-rearing diminishes (Turner *et al.* 1973; Kleinschmidt and

Kondos 1976, 1977) and life span of honey bees are shortened, which ultimately affects the productivity of the colony (Knox *et al.* 1971).

Crude protein levels of honey bee collected pollen from different plants are variable and can range from 7 to 30% (Todd and Bretherick 1942), 9.5% to 36.9% (Rayner and Langridge 1985) or 8 to 40% (Herbert 1992). Ten amino acids found in the protein of pollen have been identified as being essential for honey bee nutritional requirements (deGroot 1953). DeGroot identified these amino acids as: threonine, valine, methionine, isoleucine, leucine, phenylalanine, histidine, lysine, arginine and tryptophan. Glycine, proline and serine were not essential for growth but do exert a stimulating effect on growth at sub-optimal growth levels (deGroot 1953).

Fresh pollen is considered the best way of resupplying protein to honey bee colonies. Irradiated pollen is the ideal feedback source by commercial beekeepers when natural pollen supply is interrupted by the cessation of flowering or deleterious environmental factors such as drought, although pollen that has been collected, dried and stored is less effective than fresh pollen. Haydak (1961) showed that pollen that had been stored for one year was 24% less effective in stimulating the development of the hypopharyngeal glands whilst pollen stored for two years failed to develop the hypopharyngeal glands that are responsible for the production of worker jelly (brood food), the food fed to larvae (Standifer 1967). In terms of the amount of protein, pollen quality directly impacts on the development of these glands.

Kleinschmidt and Kondos (1976) concluded that pollens with less than 20% crude protein cannot satisfy colony requirements for optimum production. Also, individual amino acids play a crucial role in honey bee development as stated by deGroot (1953). In Australia, isoleucine has been implicated as a limiting factor in honey bee nutrition (Stace and White 1994).

The quantative lipid requirements of honey bees has not been established (Manning 2000), although Haydak and Dietz (1972) found that honey bees responded to diets containing cholesterol. There is evidence that honey bees are attracted to pollens with high lipid levels (Singh *et al.* 1999), even though the general nutritional value of some of these pollens is low when using protein and amino acid levels as a measure of honey bee nutritional value.

Only a few examples of lipid content in honey bee collected pollens have been published and the range of species reported is limited (Todd and Bretherick 1942; Youssef *et al.* 1978; Day *et al.* 1990; Singh *et al.* 1999; Manning and Harvey 2002). This could be due to the lack of knowledge of the function of lipids in honey bee nutrition. The data provided in this chapter adds to our knowledge on the lipid (fat) content of honey bee collected pollens across a broader range of floral species and provides an indication of the variation of lipid content within a single species.

Quite high concentrations of minerals, particularly potassium (K), phosphorus (P) and magnesium (Mg), are necessary to insects during their development (Dadd 1973), but excessive concentrations of sodium (Na), sodium chloride (NaCl), and calcium (Ca) have been shown to be toxic to bees (Nation and Robinson 1968; Herbert 1979; Horr 1998). High concentrations of trace elements, particularly zinc (Zn), were associated with a condition referred to as "disappearing disorder" (Anderson 1997), a syndrome occasionally reported in honey bee colonies located in north-eastern NSW and south-eastern Queensland (Warhurst and Goebel 1995). Wardell (1982) found that blueberry pollen contained 10 times as much manganese (Mn) as non-blueberry pollen (unidentified species). Honey bees foraging on blueberries were prone to infections of *Melissococcus pluton*, although the study did not establish a direct causative link. High K and/or P and low Na concentrations in honeydew honey were associated with paralysis of adult honey bees in Germany (Horn 1985). High mineral levels in honeydew have also been implicated in causing dysentery in adult bees (Imdorf *et al* 1985; Crailsheim and Pabst 1988).

Research in Australia has previously focussed on crude protein and amino acids in honey bee-collected pollen from southern Queensland, Victoria and northern NSW (Kleinschmidt and Kondos 1976; Rayner and Langridge 1985; Muss 1987; Stace 1996a). This research further adds to our understanding of the chemical composition of pollens collected by honey bees in NSW and Victoria with 33 species being analysed for the first time and provides an indication of the best flora for beekeepers to locate their colonies to ensure healthy, long-lived bees.

MATERIALS AND METHODS

Pollen samples and collection

Pollen pellet samples were collected from various sites across NSW and Victoria from June 1995 to December 1998. Pollen pellets were removed from forager honey bees as they entered the hive through a wire mesh screen of a bottom fitted pollen trap (Plate 7.1). The pellets that collected in a ventilated collection tray (Somerville 2000b) were harvested every five to seven days (Plate 7.2). All collected pollen was frozen at -20°C immediately after collection.

Plate 7.1 Bottom fitted pollen traps on hives.

Plate 7.2 Ventilated collection tray from pollen trap

Plate 7.3 Mixture of pollen pellets from a range of species.

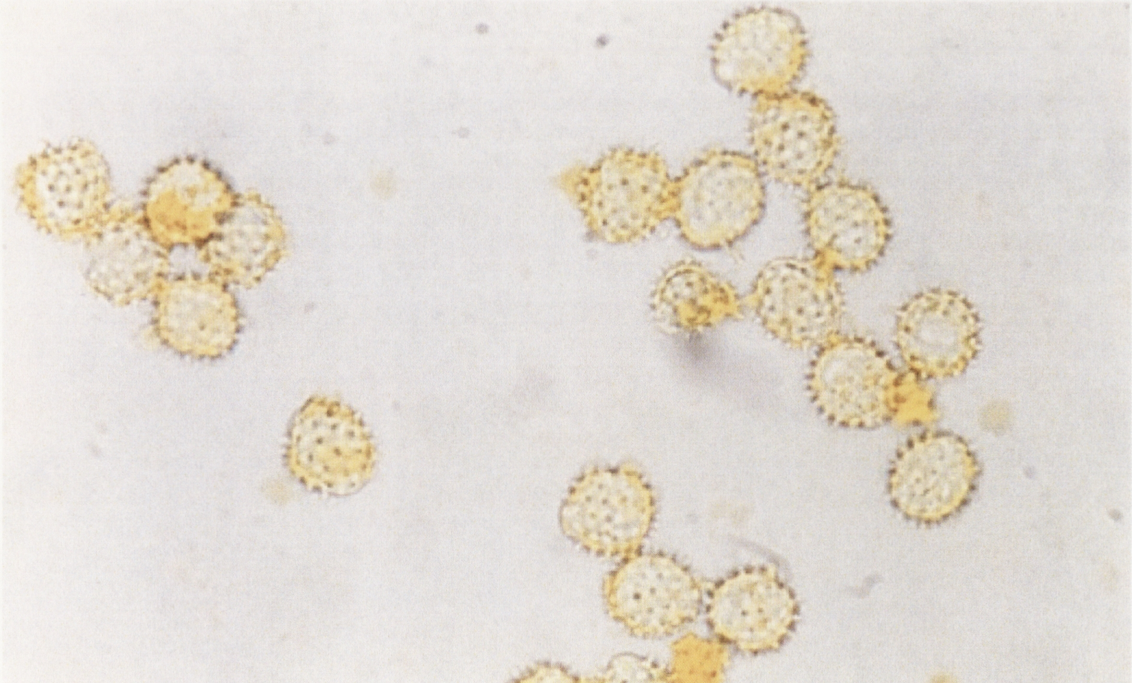


Plate 7.4 *Arctotheca calendula* pollen — magnification 400 x

Identification of pollen samples

Pollen was viewed by microscopic examination (400X magnification) and identified by comparison with the pollen from flowering plants on location (Plate 7.4). Once identified, mixed pollen collections were hand-sorted by colour for chemical analysis of individual species (Plate 7.3). Various references were used to confirm the botanical identity of floral species (Clemson 1985; Auld and Medd 1987; Fairley and Moore 1989; Brooker and Kleinig 1990a). Some plant specimens were submitted to the Royal Botanic Gardens, Sydney for identification. A total of 177 samples of pollen were sorted for analysis representing 61 floral species plus six unidentified pollens. Five samples of pollen were sent to both laboratories (refer to chemical analysis) providing data for 182 samples of pollens. The date and location of each sample collection can be found in Appendix 6, including the 61 *Echium plantagineum* pollen samples.

Chemical analysis

Pollen samples were forwarded to two laboratories and analysed for crude protein, amino acids (Table 7.2) and fat. It was necessary to utilise two laboratories due to laboratory 1 being unable to continue to provide a service mid way through the research period. Variation in laboratory technique and its possible influence on the results was checked by submitting five pollens to both laboratories. NSW Agriculture chemistry laboratory, Wollongbar processed 90 samples of honey bee collected pollen and the State Chemistry Laboratory, Werribee, Victoria processed 92 samples.

Five samples of pollen were tested including *Hypochoeris radicata*, *Angophora floribunda*, two *Echium plantagineum* pollens, plus one species from the family Papilionaceae. These pollens were tested three times for 17 amino acids and crude protein in order to determine the variability and precision of analyses provided by the State Chemistry Laboratory, Victoria. Fifty pollen samples were submitted to the same laboratory for mineral analysis.

Laboratory 1 (NSW Agriculture Chemistry Laboratory, Wollongbar): Crude protein levels were calculated by multiplying the nitrogen content by 6.25 (on average, protein is assumed to contain 16% nitrogen). The amino acids were measured as grams per 16 g of nitrogen (g/16gN). Tryptophan was not measured due to the high cost of analysis.

A modified macro Kjeldahl method for determining nitrogen was used, crude protein was calculated by multiplying 6.25 by the %N. This was based on %N in 100 g protein. Amino acids were analysed using high-pressure liquid chromatography. The Pico•Tag® method was used, which employs phenylisothiocyanate to rapidly and quantitatively derivatise both primary and secondary amino acids in a simple, one-step reaction. Amino acids were separated on a C_{18} column and total analysis time was 20 minutes, with detection limits of one picomole (Cohen *et al.* 1989). Due to the instability of methionine and cystine under acid hydrolysis conditions, the amino acids were converted to more stable derivatives by pre-oxidation prior to hydrolysis. Results were expressed as a percentage to two decimal places. Total fat levels in pollen were based on the extraction of fat with petroleum spirits. Results were expressed as a percentage of dry matter to one decimal place.

Laboratory 2 (The State Chemistry Laboratory, Werribee, Victoria): Samples were hydrolysed in 6N HCl, diluted to volume, an aliquot was taken for rotary evaporation, dried, and amino acid dissolved in a sodium citrate buffer (pH 2.2). This solution was then injected into the HPLC. The HPLC was comprised of a strong cation exchange column, which separated out the individual amino acids on the basis of pH and sodium ion strength of the buffer and pKa's of the individual amino acids. A post-column ninhydrin reaction produced coloured derivatives, which were monitored via a UV detector. The sulphur amino acids methionine and cystine required pre-oxidation with performic acid prior to hydrolysis as above.

Crude protein samples were digested in concentrated sulfuric acid with a selenium catalyst. Organic nitrogen in the sample was reduced to ammonia, which remained in the solution as ammonium sulfate. The digest was made alkaline with sodium hydroxide, and the ammonia was steam distilled into boric acid solution and titrated against standardised hydrochloric acid. The nitrogen and protein content was then calculated.

Laboratory 2 also calculated the protein recovery which was defined as nitrogen derived from the amino acids divided by nitrogen derived from all sources. This was calculated as a laboratory quality assurance measure, the figure should be between 85% and 110%, otherwise the amino acid extractions are questionable.

The fat was determined as crude fat from a solvent extract. A known amount of sample was weighed and extracted in a Soxtherm apparatus with diethyl ether. Excess solvent was removed and the extracted fat was further "dried" in an oven. The weight of extracted fat was recorded and fat content was then calculated.

The minerals were determined using inductively coupled plasma-optical emission spectroscopy (ICP-OES) Varian Liberty Model 220 ICP OES (Varian, Melbourne). A portion of the sample was digested in nitric acid in a microwave acid digestion unit (Milestone MLS — 1200 MEGA Microwave Acid Digestion System, Milestone, Leutkirch, Germany) using the following specific time and power profile: 3 min — 250 W, 30 s — 0 W, 5 min — 300 W, 30 s — O W, 5 min — 600 W, 1 min ventilation. Samples were diluted and an aerosol from the digest introduced into the high-temperature plasma generated by the ICP-OES instrument. The atomic emission spectra so produced were measured and were proportional to the concentration of the particular element in the sample. Recoveries were determined by spiking the sample matrix with a known amount of each element and determining the percentage recovery. The recovery determination was performed in duplicate with the following results: Ca (99%, 96%), K (96%, 90%), Mg (99%, 104%), Mn (104%, 109%), Na (109%, 97%), P (97%, 100%), Zn (103%, 96%), Cu (96%, 100%), Fe (100%, 101%) and S (101%, 97%).

Statistical analysis

An analysis of variance was conducted for the variability between laboratory providers (Table 7.4) and the laboratory variability within the one pollen sample (Table 7.3), performed using Genstat 5, version 4.1 (Numerical Algorithms Group, Oxford, UK, 1998). Analyses for the 63 *Echium plantagineum* pollen samples was performed using ASReml, a flexible least squares mixed models analysis package (Gilmour *et al.* 2002). Univariate mixed linear model analyses were conducted on each of the amino acids and the crude protein. In each analyses, the model fitted was Year+Location+Year. Location is the interaction of Year and Location, and Location and Year. Location was fitted as random effects. In addition, preliminary inspection of the data suggested that the variation differed between years, in some cases extremely markedly, such as for cystine, with a range of 3.6 in 1995 (1.87 to 5.46) versus 0.2 across 1996 and 1997 (1.32 to 1.52). So the implicit assumption of equal variances across all samples was clearly inadequate. To allow for this, 3 separate variance components were fitted for the residual variation in each year respectively. Sites which were only measured in one year also contained information about year effects if location was treated as a random effect, albeit in a less direct way, and the standard error when all samples were used was lower.

RESULTS

Pollen collections

The majority of pollen sample events included a mixture of species, only 24% of the collection events were composed of one species. Pollen colour was variable for some species, for example *Echium plantagineum* varied from a deep, dark purple or blue through to a light mauve, although the colour was consistent for each species in each collection event. There was an average 2.6 species in pollen collections, with up to 6 floral species identified.

Crude protein and amino acids

The means and range of the amino acids and crude protein (CP%) for the 177 bee collected pollens is shown in Table 7.1. Moisture levels and protein recovery figures were provided for 80 and 92 pollen samples. The range of moisture levels in honey bee collected pollens varied from 6.7% (*Echium plantagineum*) to 20.6% (*Eucalyptus saligna*) with a mean of 12.1%. Protein recovery varied from 72.6% to 103.1%. The crude protein levels ranged from 9.2% (*Hypochoeris radicata*) to 37.4% (*Echium plantagineum*), averaging 25.9%.

Table 7.1 Amino acid (g/16gN) crude protein (% of dry matter), protein recovery (%), and original moisture content (%). Minimum, mean and maximum values for 177 pollens representing 61 floral species.

Amino acid	Minimum	Mean	Maximum
Aspartic acid	7.05	10.8	16.9
Threonine	3.01	4.20	5.11
Serine	3.38	5.09	6.46
Glutamic acid	6.76	10.7	16.6
Proline	4.83	10.7	39.4
Glycine	3.25	4.66	9.60
Alanine	3.93	5.23	6.59
Valine	2.98	5.10	7.19
Methionine	1.00	2.34	3.60
Isoleucine	2.70	4.28	5.79
Leucine	4.94	6.76	8.68
Tyrosine	1.98	2.95	3.76
Phenylalanine	2.86	4.00	5.24
Lysine	3.25	6.36	9.53
Histidine	1.59	2.64	4.90
Arginine	3.01	5.35	8.37
Cystine	1.02	1.82	3.54
Protein recovery % [A]	72.6	88.5	103
Original moisture % [B]	6.70	12.1	20.6
Crude protein %	9.20	25.9	37.4

[A] ***Values from 92 samples only,*** [B] ***Values from 80 samples only***

Results of the analysis of 182 pollen samples (177 samples plus five pollens tested by both laboratories) analysed for 17 amino acids, protein recovery percentage, moisture content and crude protein percentage of dry matter are shown in Table 7.2. Average CP% data for 63 *Echium plantagineum* samples analysed ranged from 28.1–37.4%, nine samples of *Hyochoeris radicata* ranged from 9.2–18.2%, six samples of *Corymbia maculata* ranged from 24.9–30.4%, five samples of *Rapistrum rugosum* ranged from 21.6–24.6% and five samples of *Eucalyptus bridgesiana* ranged from 22.6–25.9%.

Table 7.2 Amino acid (g/16gN), crude protein (% of dry matter), protein recovery (%) and moisture content (%) of pollens collected by honey bees

Pollen source	Amino acid																			
	Asp.	Thr.	Ser.	Glu.	Pro.	Gly.	Ala.	Val.	Met.	Iso.	Leu.	Tyr.	Phe.	Lys.	His.	Arg.	Cys.	Protein recovery %	Original moisture %	Crude protein %
Acacia doratoxylon	7.34	3.01	3.92	9.04	10.6	3.74	3.93	4.00	2.21	2.94	5.35	2.18	3.21	4.66	2.36	6.37	1.21	75.4	19.2	24.9
A. longifolia	10.1	4.54	5.17	11.5	6.15	4.17	4.98	5.34	2.74	4.64	7.15	3.08	4.24	6.19	1.97	5.45	2.25	-	-	24.6
A. suaveolens	10.8	3.71	5.26	10.1	7.47	3.86	5.09	3.95	2.84	3.41	6.38	2.99	3.51	5.00	1.73	4.66	1.93	-	-	21.7
Acacia spp.	11.1	4.63	5.76	12.2	13.1	4.24	5.29	5.49	2.54	4.56	7.28	3.34	4.08	5.35	2.12	7.20	1.85	-	-	23.8
Angophora floribunda	8.86	4.17	5.25	10.5	14.6	4.72	5.23	5.47	2.34	4.71	7.19	2.99	4.25	5.57	2.70	6.07	2.49	-	-	21.0
"	11.2	4.79	6.03	12.8	15.4	5.65	6.25	5.99	2.06	4.70	8.67	3.55	5.09	6.62	2.68	7.02	1.31	103.1	17.5	22.9
"	8.94	3.95	5.15	11.0	13.6	4.71	5.17	5.27	2.14	3.97	7.02	2.79	4.09	5.70	2.58	6.09	1.45	89.3	17.4	22.3
Arctotheca calendula	10.4	4.16	5.35	8.81	10.1	5.45	5.22	4.34	2.25	3.74	5.92	2.84	3.89	7.59	3.77	3.75	1.57	85.9	14.6	17.3
Asphodelus fistulosus	7.22	3.53	4.11	8.01	39.4	3.25	5.04	4.06	1.79	3.22	5.31	2.24	3.06	3.77	1.64	3.40	1.02	88.9	13.2	22.5
Banksia ericifolia	10.6	4.20	5.79	13.1	10.2	4.68	5.38	4.47	2.73	3.75	6.40	3.22	3.83	6.00	2.98	6.57	2.88	-	-	28.6
B. serrata	9.72	3.81	5.37	12.6	7.83	4.22	4.63	4.84	2.27	3.61	5.77	2.77	3.71	5.49	2.37	7.24	2.03	87.6	8.80	33.3
Brassica napus	8.09	4.92	5.66	10.2	6.42	4.62	5.29	5.36	2.64	4.95	6.95	3.05	4.39	8.38	2.17	5.09	2.33	-	-	22.1
"	9.45	4.82	6.36	11.1	5.94	4.43	5.27	4.90	1.94	4.34	6.98	2.91	4.21	7.94	2.10	5.17	1.22	83.6	-	23.5
"	10.6	5.11	6.35	11.6	8.20	5.04	5.78	5.57	2.32	4.47	7.57	2.69	4.03	8.45	2.72	4.83	1.51	92.1	10.2	26.1
"	9.14	3.93	5.02	10.9	12.7	4.81	5.19	5.15	2.03	3.82	6.57	2.77	3.78	5.55	2.52	6.26	1.27	88.2	8.50	23.8
"	9.32	5.03	5.98	10.7	6.94	4.73	5.41	5.49	2.51	5.03	7.17	3.14	4.47	8.28	2.19	5.13	2.41	-	-	23.6
Caduus nutans	8.39	3.78	4.65	9.05	21.0	4.15	5.47	4.78	2.25	4.19	5.72	2.83	3.44	6.13	3.61	3.69	3.18	-	-	15.1
Carthamus lanatus	10.0	4.05	4.28	10.2	15.7	5.14	6.05	5.69	2.55	5.03	6.94	2.72	4.18	6.77	4.43	4.48	2.46	-	-	18.1
Casuarina littoralis	9.04	3.19	4.67	9.21	19.0	3.85	4.57	3.30	2.48	2.71	5.63	2.64	2.86	3.50	1.59	5.82	2.39	-	-	11.5
"	9.40	3.67	5.13	10.2	21.8	4.30	4.74	4.17	2.26	3.40	6.41	3.06	3.57	4.94	1.91	6.40	2.40	-	-	12.9
"	9.51	4.16	4.81	10.1	13.2	4.33	4.80	4.74	2.58	3.91	6.06	2.69	3.44	4.66	1.68	7.09	2.56	-	-	13.1

Table 7.2 cont.

Pollen source	Amino acid																			
	Asp.	Thr.	Ser.	Glu.	Pro.	Gly.	Ala.	Val.	Met.	Iso.	Leu.	Tyr.	Phe.	Lys.	His.	Arg.	Cys.	Protein recovery %	Original moisture %	Crude protein %
Centaurea solstitialis	9.32	4.20	6.12	10.4	15.6	5.23	5.67	4.94	2.14	4.52	6.96	3.07	3.96	6.34	3.74	4.41	1.87	-	-	20.6
Chondrilla juncea	12.1	4.67	4.85	12.4	4.83	5.46	5.94	7.19	3.05	5.77	8.20	3.58	5.17	5.91	2.96	6.03	2.54	-	-	23.4
"	10.2	3.68	5.11	10.1	7.32	4.24	5.12	3.80	3.60	3.10	6.02	2.85	3.41	4.99	2.20	4.52	3.02	-	-	22.2
Cirsium vulgare	8.95	3.63	3.77	9.27	17.3	4.19	5.76	5.09	2.52	4.54	6.19	2.58	3.52	6.78	3.13	3.91	2.56	-	-	16.1
"	9.53	4.06	5.28	10.6	15.0	4.22	5.72	4.72	1.98	4.10	6.34	3.07	3.72	6.87	3.43	4.41	1.61	87.8	-	17.3
"	9.39	4.31	5.28	10.2	19.0	4.57	5.79	5.16	2.38	4.67	6.71	2.95	4.02	6.86	3.20	4.32	2.84	-	-	17.6
Citrus spp.	10.4	4.44	5.57	11.7	12.6	4.35	5.43	5.33	2.08	4.22	7.21	3.18	4.28	9.53	2.30	5.22	1.17	102	10.7	18.5
Corymbia gummifera	10.1	4.35	5.67	12.1	11.1	5.27	5.47	5.36	2.31	4.04	7.28	3.19	4.72	6.60	3.09	7.74	1.39	96.4	13.5	26.9
C. maculata	9.63	3.83	5.20	11.0	11.4	4.47	5.13	4.74	2.19	3.87	6.69	2.72	3.89	5.79	2.65	7.65	1.36	88.7	-	24.9
"	8.76	3.68	4.67	9.68	11.7	4.38	4.84	4.72	2.03	3.63	6.31	2.58	3.77	5.50	2.55	6.63	1.41	84.1	19.6	30.4
"	10.8	4.15	5.27	12.3	13.0	5.44	5.55	5.16	2.26	3.88	7.59	2.99	4.40	6.44	2.74	8.04	1.49	97.8	17.0	29.5
"	11.7	4.40	5.65	13.5	13.8	5.52	5.71	5.44	2.19	4.09	8.06	3.09	4.54	6.94	2.90	8.37	1.39	103	14.4	28.4
"	11.0	3.82	5.05	11.7	13.4	5.04	5.37	5.04	2.25	3.67	7.26	2.66	3.97	6.01	2.80	7.13	1.36	93.8	13.3	29.1
"	11.6	4.06	5.39	12.3	13.7	5.44	5.62	5.20	2.29	3.77	7.57	2.75	4.11	6.20	2.91	7.84	1.41	98.4	13.8	28.7
Echium plantagenium [C]	13.3	4.43	4.99	11.1	7.02	4.75	5.29	5.36	2.44	4.68	6.88	3.04	4.06	6.58	2.68	4.96	1.89	-	-	32.8
E. vulgare	12.6	4.69	5.37	10.8	6.32	4.79	5.44	5.45	2.28	4.60	7.03	3.25	4.32	5.08	2.36	4.89	1.37	86.1	14.4	34.9
Eucalyptus albens	7.99	3.41	4.69	9.88	12.0	4.71	5.00	4.28	2.70	3.38	6.00	2.88	3.44	5.16	1.95	5.79	2.47	-	-	22.1
"	7.86	3.78	4.85	11.2	11.7	4.98	5.24	5.30	2.69	4.20	6.89	3.17	3.90	5.37	2.30	6.41	2.47	-	-	22.4
"	9.35	3.87	4.88	11.1	13.5	4.45	4.92	4.74	2.55	3.77	6.61	3.17	3.89	4.78	1.73	5.77	2.08	-	-	22.5
"	8.50	3.86	4.83	10.4	11.6	4.67	5.01	4.92	2.33	3.59	6.47	2.84	3.80	5.60	2.61	6.78	1.35	87.7	16.7	23.1
E. blakelyi	9.94	3.93	5.11	11.9	12.8	5.25	5.44	5.08	2.28	3.74	7.16	3.00	4.22	6.26	2.13	6.45	1.38	96.2	9.40	28.8
E. bridgesiana	8.96	4.00	5.22	10.8	15.9	4.91	5.55	5.09	2.85	4.24	7.02	2.83	3.98	5.60	2.43	6.58	2.24	-	-	23.1
"	8.97	3.74	4.82	11.4	14.6	4.73	5.19	4.94	2.00	3.52	6.79	2.71	3.89	5.92	2.61	5.70	1.18	87.6	11.8	25.9

Table 7.2 cont.

Pollen source	Amino acid																			
	Asp.	Thr.	Ser.	Glu.	Pro.	Gly.	Ala.	Val.	Met.	Iso.	Leu.	Tyr.	Phe.	Lys.	His.	Arg.	Cys.	Protein recovery %	Original moisture %	Crude protein %
"	9.71	3.81	3.60	11.5	15.8	5.25	5.80	6.26	2.21	5.13	7.58	3.01	4.27	6.56	2.35	6.42	1.87	-	-	23.0
"	9.75	3.64	3.45	11.9	15.7	5.09	5.57	6.05	2.71	4.99	7.31	2.72	4.17	6.36	2.49	5.92	2.27	-	-	22.6
"	8.75	3.74	4.91	10.2	15.3	4.26	5.03	4.84	2.61	3.86	6.73	3.12	3.96	5.15	1.59	5.77	1.96	-	-	23.5
"	8.16	3.61	4.64	10.2	12.7	4.30	4.92	4.84	2.20	3.55	6.16	2.54	3.67	5.57	2.18	5.38	1.34	82.2	13.2	24.9
E. camaldulensis	9.94	3.97	4.70	11.3	14.3	4.80	5.35	5.45	2.99	4.53	6.86	2.78	3.82	5.87	2.33	6.48	2.39	-	-	22.6
"	9.12	3.82	4.92	10.7	12.0	4.61	4.98	4.98	2.52	3.60	6.46	2.74	3.75	5.49	2.33	6.23	1.38	86.7	9.50	25.6
E. delegatensis	9.51	3.68	3.69	11.8	18.8	4.87	5.36	5.83	2.05	4.86	7.14	2.96	4.33	6.04	2.27	6.05	1.76	-	-	23.0
E. dumosa	8.60	3.60	4.63	10.1	12.7	4.50	4.87	4.85	2.15	3.54	6.28	2.61	3.64	5.67	2.46	7.16	1.43	87.7	15.5	22.2
"	8.88	3.65	4.85	10.8	12.1	4.64	4.81	4.78	1.92	3.52	6.47	2.70	4.08	5.80	2.84	8.15	1.46	90.4	8.20	20.5
E. fibrosa	8.88	3.41	3.54	11.0	11.9	4.69	4.96	5.34	2.51	4.39	6.63	2.59	3.70	5.58	2.05	6.50	2.24	-	-	20.5
E. globoidea	10.2	4.02	5.11	10.9	12.2	5.15	5.44	5.03	2.25	3.68	7.25	2.97	4.24	6.34	2.78	7.10	1.30	92.6	17.7	29.4
E. longifolia	7.92	3.67	4.70	10.3	15.1	4.44	4.90	4.75	2.99	3.84	6.26	2.66	3.72	5.82	1.84	6.50	2.46	-	-	24.9
"	7.41	3.46	4.96	10.7	15.5	4.97	5.33	4.49	2.39	3.50	6.32	2.96	3.54	5.03	1.75	6.33	2.10	-	-	25.4
E. macrorhyncha	8.48	3.34	4.99	9.98	15.7	4.66	4.83	4.29	2.23	3.40	6.12	2.93	3.58	5.14	2.10	5.59	1.94	-	-	24.2
"	9.11	3.48	3.38	10.6	15.6	4.71	5.47	5.75	2.11	4.79	6.86	2.62	3.89	6.24	2.50	5.65	1.84	-	-	22.1
"	9.39	3.71	4.73	11.7	12.1	4.67	5.76	5.37	2.11	3.84	6.86	2.47	3.53	6.07	2.33	5.49	1.28	88.1	8.50	26.9
"	9.76	3.88	5.04	12.3	12.3	5.01	6.01	5.64	2.22	3.95	7.25	2.54	3.65	6.34	2.33	5.57	1.34	91.4	13.2	26.2
E. mannifera	8.57	3.91	5.00	10.9	12.5	4.59	5.14	4.96	2.43	3.65	6.57	2.80	4.19	6.09	2.45	5.95	1.35	87.2	12.0	28.1
"	7.86	3.57	4.51	9.94	12.8	4.25	4.80	4.78	2.18	3.54	6.17	2.53	3.66	5.61	2.23	5.55	1.41	81.5	11.1	24.3
E. microcarpa	8.56	3.92	4.94	11.0	10.1	4.76	5.16	5.11	2.07	3.77	6.50	2.75	3.85	5.96	2.38	6.44	1.27	86.2	10.2	23.6
E. polyanthemos	8.73	3.80	4.76	10.5	11.2	4.66	5.02	4.90	2.24	3.61	6.39	2.79	3.73	5.66	2.54	6.23	1.39	86.4	14.8	22.4
E. punctata	8.00	3.50	4.52	9.55	12.7	4.35	4.84	4.76	1.68	3.45	6.03	2.58	3.51	5.42	2.26	5.57	1.05	80.7	9.30	27.3
E. robusta	8.82	3.74	4.70	10.0	12.1	4.46	4.93	5.08	2.46	4.00	6.64	3.19	3.97	5.29	1.82	5.99	2.02	-	-	22.6
E. saligna	9.98	4.00	5.21	11.5	10.5	5.34	5.56	5.19	1.00	3.72	7.26	2.90	4.14	5.89	2.02	6.65	1.22	94.3	20.6	27.6
E. sclerophylla	9.77	4.11	5.28	11.2	11.3	4.82	5.35	5.2	2.52	3.88	6.91	2.82	4.13	6.08	2.50	7.09	1.47	93.2	14.2	29.7
E. socialis	8.55	3.49	4.52	10.4	11.3	4.40	4.67	4.50	2.00	3.36	5.97	2.52	3.57	5.36	2.49	7.18	1.39	86.1	9.70	26.6
E. viminalis	9.06	3.75	3.90	11.0	15.5	4.90	5.34	5.62	2.48	4.74	7.08	2.76	3.94	6.22	2.47	5.46	2.14	-	-	23.7

Table 7.2 cont.

Pollen source	Amino acid																			
	Asp.	Thr.	Ser.	Glu.	Pro.	Gly.	Ala.	Val.	Met.	Iso.	Leu.	Tyr.	Phe.	Lys.	His.	Arg.	Cys.	Protein recovery %	Original moisture %	Crude protein %
Fagopyrum esculentum	9.85	4.20	5.39	16.6	5.04	3.91	5.50	5.02	1.98	4.46	6.83	3.34	3.85	6.89	2.65	4.32	1.06	86.8	-	11.4
Hakea sericea	9.63	4.26	5.32	12.1	15.7	3.95	4.68	4.78	2.04	3.93	6.59	2.90	3.81	4.66	2.40	6.41	2.95	-	-	18.4
Helianthus annuus	9.25	3.96	4.60	9.11	6.73	4.95	4.56	4.57	2.24	4.28	6.61	2.85	3.70	5.75	4.61	3.71	3.54	-	-	13.8
"	9.32	4.06	4.75	9.70	6.36	4.79	5.10	4.64	1.82	4.00	6.41	2.87	3.55	6.21	4.79	3.98	2.14	80.8	-	12.9
Hypochoeris radicata	7.05	3.24	4.80	7.45	11.8	3.79	4.17	3.41	2.02	3.13	4.94	2.18	3.06	7.48	3.84	3.14	1.46	72.6	-	15.1
"	8.28	3.71	4.90	8.03	13.6	4.53	4.64	3.90	1.82	3.33	5.77	2.52	3.57	8.12	4.22	3.68	1.40	82.5	16.0	17.0
"	8.74	4.06	5.57	8.63	15.2	4.92	5.06	4.27	2.11	3.63	6.10	2.74	4.10	8.88	4.90	3.93	1.57	90.3	14.2	17.1
"	9.26	4.08	5.33	8.60	13.6	4.76	4.89	4.27	2.06	3.51	5.94	2.77	3.90	7.41	4.40	3.63	1.48	85.5	10.5	18.2
"	8.28	3.81	5.13	8.15	15.1	4.52	4.77	4.17	1.99	3.62	5.74	2.57	3.76	7.80	4.18	3.32	1.41	84.0	12.2	17.9
"	8.22	3.05	5.02	7.73	15.9	4.33	4.61	2.98	2.18	2.70	5.01	2.53	3.05	6.61	3.75	3.01	2.55	-	-	15.6
"	8.54	4.17	5.10	8.88	16.8	4.32	5.07	4.55	2.15	4.27	6.24	2.76	3.86	7.80	3.27	3.81	2.40	-	-	14.1
"	8.33	3.85	5.34	8.30	16.9	4.64	5.04	4.46	2.05	3.77	5.97	2.46	3.56	8.17	3.84	3.38	1.48	86.4	14.0	17.1
"	7.21	3.17	6.00	6.76	7.01	4.69	4.82	3.84	1.43	3.15	5.59	2.42	3.04	8.58	3.12	3.57	2.18	80.3	12.4	9.20
Lavandula spp.	9.24	4.17	4.61	10.2	18.1	4.57	5.25	4.54	2.21	3.59	6.04	3.11	4.11	6.38	3.67	4.31	1.67	89.3	13.6	19.4
Lupinus angustifolius	11.7	4.36	5.30	10.7	15.2	4.49	5.38	5.35	2.07	4.44	7.96	3.09	4.24	3.25	2.22	4.70	1.22	92.3	13.0	34.7
"	11.3	4.99	6.05	11.0	13.9	4.62	5.57	5.72	2.13	4.91	8.05	3.71	5.06	7.40	2.80	5.50	1.15	96.4	16.0	33.7
Papilionaceae spp.	9.44	3.95	4.94	9.82	10.7	4.41	5.07	4.96	2.36	3.77	6.55	2.74	3.84	5.71	2.69	7.11	1.34	90.0	19.0	19.7
"	11.1	4.52	5.56	10.8	13.5	4.04	5.04	4.98	2.72	4.25	7.39	3.70	4.38	5.65	2.64	4.89	1.99	-	-	17.1
"	9.45	3.70	4.44	9.73	11.4	3.98	4.77	4.75	1.99	3.66	6.33	2.66	3.73	5.59	2.71	7.05	1.12	84.9	19.1	23.3
Prunus dulcis	10.6	4.52	5.30	10.4	11.3	4.15	5.25	5.11	2.57	4.31	6.41	3.12	3.88	6.48	1.94	5.48	2.15	-	-	25.4
"	11.7	4.47	5.73	10.4	12.5	4.24	5.40	4.83	2.38	4.00	6.85	3.30	4.15	5.87	1.82	5.15	1.95	-	-	24.8
Pyrus communis	10.6	4.42	5.69	10.7	5.73	4.28	5.37	5.4	2.43	4.11	6.89	2.80	4.15	6.42	2.64	4.77	1.32	84.4	11.5	26.2

Table 7.2 cont.

Pollen source	Amino acid																			
	Asp.	Thr.	Ser.	Glu.	Pro.	Gly.	Ala.	Val.	Met.	Iso.	Leu.	Tyr.	Phe.	Lys.	His.	Arg.	Cys.	Protein recovery %	Original moisture %	Crude protein %
Rapistrum rugosum	8.61	4.67	5.73	9.81	9.87	4.64	5.54	5.27	2.29	4.86	7.05	3.13	4.44	8.47	2.13	5.09	2.19	-	-	21.6
"	9.19	4.75	5.93	9.38	8.28	4.47	5.23	4.88	2.61	4.29	6.83	3.05	4.17	6.58	2.09	5.11	2.01	-	-	22.7
"	9.96	4.73	5.82	10.6	14.1	4.42	5.11	5.02	2.54	4.50	6.97	3.22	4.25	6.46	1.85	5.58	2.01	-	-	21.8
"	10.0	4.59	5.87	10.9	11.0	4.54	5.10	4.79	2.31	4.33	6.97	3.44	4.29	6.80	1.92	4.79	2.01	-	-	22.9
"	8.95	4.55	5.85	10.9	7.62	4.50	5.01	4.70	1.85	3.86	6.51	2.62	4.10	6.96	2.25	4.78	1.14	81.6	10.6	24.6
Salix discolour	10.1	4.50	5.92	12.3	4.96	4.70	5.43	5.51	2.52	4.75	7.49	3.16	4.39	7.16	2.28	6.29	2.18	-	-	21.9
S. fragilis	9.06	3.41	5.24	10.2	5.51	3.60	4.09	3.93	2.16	3.28	5.62	2.70	3.29	5.25	1.80	6.57	2.40	-	-	14.8
"	9.72	3.89	5.71	11.0	5.24	3.84	4.57	4.52	2.44	3.90	6.18	2.86	3.57	5.85	1.99	6.82	2.26	-	-	15.1
Senecio madagascariensis	9.10	4.04	5.19	8.32	11.5	4.34	5.07	4.08	2.32	3.57	5.76	3.05	3.39	5.44	3.20	4.36	2.38	-	-	12.4
Sisymbrium officinale	10.3	5.06	6.23	10.9	8.82	4.74	5.68	5.34	2.43	4.92	7.31	3.25	4.51	8.71	2.25	5.33	2.28	-	-	22.0
"	9.33	4.23	5.68	9.19	8.03	4.20	5.04	3.27	2.77	3.14	5.63	2.58	3.21	5.81	1.79	4.10	2.60	-	-	22.3
"	10.1	4.66	4.72	10.4	9.93	5.06	5.59	5.70	2.64	5.34	7.23	2.80	4.20	8.09	2.67	4.99	2.53	-	-	22.4
Trifolium balansae	9.63	4.70	5.48	10.5	16.7	4.34	5.59	5.66	2.41	5.13	7.35	3.12	4.43	5.96	2.41	4.86	2.09	-	-	23.4
"	9.27	4.58	5.39	10.5	14.5	4.13	5.27	5.27	2.12	4.34	6.96	3.05	4.35	6.08	2.48	4.62	1.12	87.7	13.2	27.2
T. repens	9.41	4.57	5.47	10.2	14.4	4.10	5.38	5.27	2.18	4.44	6.98	3.12	4.28	5.86	2.49	4.65	1.13	87.7	12.6	25.9
Ulex europaeus	10.7	4.51	5.6	10.7	11.8	4.02	5.08	5.14	2.35	4.43	7.15	3.39	4.39	5.99	2.26	4.73	1.86	-	-	28.4
Vaccinium spp.	9.32	3.78	4.37	10.3	5.81	4.37	4.71	5.44	2.29	4.72	6.65	1.98	3.51	6.37	1.98	5.64	2.61	-	-	13.9
Vicia faba	9.19	4.57	5.18	9.85	18.7	4.06	5.08	5.22	2.24	4.83	6.70	3.07	4.15	6.17	2.11	5.10	1.75	-	-	24.4
V. sativa	9.14	4.55	5.54	11.0	17.1	4.06	5.55	5.15	2.39	4.66	7.02	3.02	4.36	6.74	1.98	4.72	1.91	-	-	24.1
"	10.1	5.00	6.13	12.1	18.6	4.46	6.05	5.68	2.36	5.13	7.80	3.29	4.80	7.37	2.18	5.24	1.85	-	-	24.0
Zea mays	9.61	5.11	6.00	9.60	13.6	9.60	6.59	5.90	1.57	4.84	6.82	3.18	3.84	5.55	1.86	4.70	1.53	-	-	14.9
Unidentified	11.4	4.41	4.70	11.2	11.5	4.90	5.60	6.12	2.97	5.46	7.84	3.41	5.24	6.74	2.35	5.78	2.51	-	-	17.2
"	9.62	4.53	5.50	10.6	14.3	4.62	5.46	5.11	2.54	4.45	6.66	3.05	4.04	6.55	2.71	4.25	2.39	-	-	19.9
"	9.49	4.79	5.57	10.6	18.5	4.47	5.58	5.83	2.52	5.40	7.87	3.51	4.67	6.04	2.20	4.91	2.11	-	-	21.9

Table 7.2 cont.

Pollen source	Amino acid																			
	Asp.	Thr.	Ser.	Glu.	Pro.	Gly.	Ala.	Val.	Met.	Iso.	Leu.	Tyr.	Phe.	Lys.	His.	Arg.	Cys.	Protein recovery %	Original moisture %	Crude protein %
"	8.38	4.52	5.06	8.84	11.4	4.36	4.63	4.20	1.81	3.75	5.41	2.61	3.34	6.09	3.08	3.70	2.56	-	-	12.4
"	10.1	4.64	6.43	11.7	14.5	5.45	5.38	5.66	2.32	4.27	7.37	3.38	5.24	5.59	3.48	6.51	1.25	98.5	12.6	23.1
"	13.5	5.03	6.46	12.6	5.95	5.22	6.07	6.20	1.96	5.02	8.68	3.76	5.22	7.61	3.32	6.23	1.44	102	7.7	21.0

[C]Mean of pollen samples for *Echium plantagineum* (n=63)

Variation in laboratory technique

The coefficients of variation (CV%) for each amino acid and the CP% are provided in Table 7.3 for the five samples of pollen analysed by Laboratory 2 three times. Lysine and proline were above the 5% confidence level at 6.1 and 6.7%, all the remaining amino acids and the CP% were below 5% confidence level for Laboratory 2.

Table 7.3 Variation of amino acids and crude protein of five pollen samples tested by Laboratory 2.

Variants	**CV %**
Aspartic acid	2.4
Threonine	4.0
Serine	3.9
Glutamic acid	2.6
Proline	6.7
Glycine	3.2
Alanine	3.4
Valine	3.8
Methionine	2.8
Isoleucine	4.4
Leucine	3.0
Tyrosine	4.5
Phenylalanine	4.7
Lysine	6.1
Histidine	2.9
Arginine	3.8
Cystine	2.9
Crude protein %	2.4

Cystine, methionine and crude protein levels were significantly different ($P<0.05$) between laboratory providers (Table 7.4). Cystine and methionine were consistently higher and the crude protein was consistently lower in Laboratory 1. The reasons for the variation between laboratories, whether through different chemical analysis, or precise technique, are not clear.

Table 7.4 Differences of chemistry analysis of 5 pollen samples between two laboratories. (Amino acids g/16N, Protein % of dry matter)

	Eucalyptus bridgesiana		***Brassica napus***		***Angophora floribunda***		***Echium plantagineum* (Bathurst)**		***Echium plantagineum* (Goulburn)**		**F.probability**
Aspartic acid	8.96	8.97	8.09	9.45	8.86	11.2	13.3	13.2	11.7	14.1	0.09
Threonine	4.00	3.74	4.92	4.82	4.17	4.79	4.56	4.18	4.29	4.51	0.92
Serine	5.22	4.82	5.66	6.36	5.25	6.03	5.19	5.23	4.90	5.57	0.19
Glutamic acid	10.8	11.4	10.2	11.1	10.5	12.8	11.1	11.1	10.5	11.8	0.07
Proline	15.9	14.6	6.42	5.94	14.6	15.4	7.25	6.13	7.12	6.31	0.19
Glycine	4.91	4.73	4.62	4.43	4.72	5.65	4.69	4.22	4.35	4.55	0.82
Alanine	5.55	5.19	5.29	5.27	5.23	6.25	5.17	5.02	5.08	5.44	0.52
Valine	5.09	4.94	5.36	4.90	5.47	5.99	5.48	4.74	5.12	5.15	0.49
Methionine	2.85	2.00	2.64	1.94	2.34	2.06	2.65	2.18	2.63	2.18	0.01
Isoleucine	4.24	3.52	4.94	4.34	4.71	4.70	4.89	4.28	4.64	4.62	0.06
Leucine	7.02	6.79	6.95	6.98	7.19	8.67	6.83	6.58	6.49	7.09	0.57
Tyrosine	2.83	2.71	3.05	2.91	2.99	3.55	3.31	2.90	2.87	3.07	0.92
Phenylalanine	3.98	3.89	4.39	4.21	4.25	5.09	3.96	3.72	4.02	3.95	0.64
Lysine	5.60	5.92	8.38	7.94	5.57	6.62	5.86	6.57	7.05	7.07	0.13
Histidine	2.43	2.61	2.17	2.10	2.70	2.68	2.52	2.18	2.23	2.61	0.89
Arginine	6.58	5.70	5.09	5.17	6.07	7.02	5.18	4.87	4.87	5.36	0.87
Cystine	2.24	1.18	2.33	1.22	2.49	1.31	2.40	1.38	2.31	1.43	<0.001
Crude protein %	23.1	25.9	22.1	23.5	21.0	22.9	30.9	31.6	29.0	29.9	0.02
Laboratory	NSW	Vic	NSW	Vic	NSW	Vic	NSW	Vic	NSW	Vic	-

Variability of CP% and amino acid content for *Echium plantagineum* pollen

Year effect: There were significant differences between years for crude protein and most amino acids (Table 7.5). For 6 amino acids (serine, proline, glycine, methionine, isoleucine, cystine) and crude protein, there was a significant difference between the average of 1995 and each of 1996 and 1997, but no significant difference between 1996 and 1997. The averages for serine and crude protein both increased from 1995 to 1996/7, but the averages for the other amino acids all decreased. The direction of these differences largely corresponded with the differences observed from the 5 samples which were measured at both laboratories (Table 7.4).

Table 7.5 Year effects on amino acid composition and crude protein levels in *Echium plantagineum* honey bee-collected pollen.

	1995	1996	1997	F-stat	P-value
Aspartic acid	13.38^{b}	12.51^{a}	14.19^{c}	15.35	P<0.001
Threonine	4.40	4.48	4.49	2.23	ns
Serine	4.72^{a}	5.22^{b}	5.20^{b}	5.48	P<0.05
Glutamic acid	11.21^{b}	10.79^{a}	11.46^{b}	7.41	P<0.01
Proline	7.43^{b}	6.69^{a}	6.70^{a}	11.39	P<0.01
Glycine	4.93^{b}	4.61^{a}	4.69^{a}	6.80	P<0.05
Alanine	5.38^{b}	5.15^{a}	5.35^{b}	5.34	P<0.05
Valine	5.57	5.19	5.23	3.53	ns
Methionine	2.61^{b}	2.32^{a}	2.28^{a}	24.43	P<0.001
Isoleucine	5.08^{b}	4.35^{a}	4.37^{a}	18.81	P<0.001
Leucine	6.95	6.80	6.96	1.31	ns
Tyrosine	3.04	3.08	3.01	0.60	ns
Phenylalanine	4.16	4.05	3.93	4.80	ns
Lysine	6.94^{b}	6.22^{a}	6.65^{b}	11.69	P<0.01
Histidine	2.64^{a}	2.58^{a}	2.93^{b}	8.38	P<0.01
Arginine	5.00	4.92	4.92	0.55	ns
Cystine	2.44^{b}	1.44^{a}	1.41^{a}	39.75	P<0.001
Crudeprotein	30.86^{a}	34.60^{b}	34.77^{b}	44.22	P<0.001

Fat

The lipid (fat) content as determined by the chemical analyses of 172 pollens ranged from 0% for *Eucalyptus macrorhyncha* to 11.2% for *Hypochoeris radicata* with a mean of 2.5%. The lipid contents from 61 *Echium plantagineum* pollens ranged from 0.6 to 2.5% with a mean of 1.6%.

The lipid content expressed as a percent of dry matter for the 61 species, in alphabetical order: *Acacia doratoxylon* 0.9; *A. longifolia* 1.4; *A. suaveolens* 2.5; *Acacia* spp. 1.2; *Angophora floribunda* 1.1, 1.5, 1.6; *Arctotheca calendula* 3.4; *Asphodelus fistulosus* 4.5; *Banksia ericifolia* 2.5; *B. serrata* 1.9; *Brassica napus* 1.8, 6.8, 6.9, 7.3, 7.3; *Caduus nutans* 2.3; *Carthamus lanatus* 3.9; *Casuarina littoralis* 1.2, 1.4, 3.3; *Centaurea solstitialis* 2.8; *Chondrilla juncea* 2.6, 3.4; *Cirsium vulgare* 1.5, 2.6, 3.7; *Citrus* spp. 3.0; *Corymbia gummifera* 1.6; *C. maculata* 1.1, 1.3, 1.4, 1.5, 2.0, 2.0; *Echium plantagineum* av. 1.6 (n=61); *E. vulgare* 4.1; *Eucalyptus albens* 2.3, 2.5, 2.6, 4.2; *E. blakelyi* 1.5; *E. bridgesiana* 0.4, 0.6, 1.1, 1.1, 1.3, 1.7; *E. camaldulensis* 1.3, 4.6; *E. dumosa* 1.9, 1.4; *E. fibrosa* 2.2; *E. delegatensis* 1.9; *E. globoidea* 1.2; *E. longifolia* 2.4; *E. macrorhyncha* 0.0, 1.0, 2.2, 2.6; *E. mannifera* 0.9, 1.5; *E. micocarpa* 3.0; *E. polyanthemos* 3.9; *E. punctata* 2.0; *E. robusta* 1.4; *E. saligna* 1.5; *E. sclerophylla* 2.3; *E. socialis* 1.8; *E. vinimalis* 0.5; *Fagopyrum esculentum* 2.2; *Hakea sericea* 2.8; *Helianthus annuus* 1.4, 1.1; *Hyochoeris radicata* 5.3, 5.9, 6.6, 7.4, 7.4, 8.2, 8.5, 9.2, 11.2; *Lavandula* spp. 2.9; *Lupinus angustifolius* 2.7, 3.1; Papilionaceae 1.6, 1.7; *Prunus dulcis* 1.9, 2.7; *Pyrus communis* 1.8; *Rapistrum rugosum* 5.2, 5.4, 5.9, 6.5, 7.0; *Salix discolour* 3.1; *S. fragilis* 1.5, 2.1; *Senecio madagascariensis* 2.4; *Sisymbrium officinale* 5.4, 5.7, 6.4; *Trifolium balansae* 1.5, 2.3; *T. repens* 2.5; *Ulex europaeus* 2.1; *Vaccinium* spp. 2.0; *Vicia faba* 1.7; *V. sativa* 1.7, 1.8; *Zea mays* 1.8.

Minerals

There was a significant variation between species in the concentration of elements in pollen, although the proportion of elements within species remained reasonably constant (Table 7.6). Sixty to 70% of all species fell below the mean for Ca, Cu, Fe, K, Mg, Mn and Na. The number of species below and above the mean for P, S and Zn was about the same.

Corymbia maculata pollen had the highest concentration of Cu and Mn of the 34 species (Table 7.5), and was 26% higher in Cu concentration than those of the next species, *Eucalyptus punctata*. *Eucalyptus punctata* pollen had the highest concentration of Fe at 520 mg/kg, which was 271% higher than the next highest Fe of 140 mg/kg in *Eucalyptus albens* and *Echium plantagineum*. Samples of *E. plantagineum* pollen had a high concentration of P and S, when compared with the mean of all pollens (Table 7.6). Why there was a very high concentration of Zn in one sample of *Echium plantagineum* pollen was not clear.

Samples of *Brassica napus* had a high concentration of Mg and Ca and a low concentration of Fe. *Hypochoeris radicata* showed low concentrations for the following 6 elements: Fe, K, Mg, P, S and Zn. Three species, *Banksia ericifolia, Casuarina littoralis* and *Eucalyptus punctata*, had the highest concentration (290–480 mg/kg) of Na in pollen. These three species were from the Shoalhaven area of NSW, indicating that this drainage-coastal area may have influenced the Na concentration in pollen.

Table 7.6 Concentration (mg/kg) of major (K, P, S, Ca and Mg) and minor (Na, Fe, Zn, Mn and Cu) elements in honey bee-collected pollen.

Species	**K**	**P**	**S**	**Ca**	**Mg**	**Na**	**Fe**	**Zn**	**Mn**	**Cu**
Acacia spp.	5000	3900	2000	670	950	110	62	60	9	4
Angophora floribunda	6200	4000	2100	720	790	77	71	97	42	16
Arctotheca calendula	2600	2700	1500	1200	700	87	23	28	7	12
Asphodelus fistulosus	38000	3100	1800	1100	790	86	52	34	22	4
Banksia ericifolia	6000	5300	3400	360	820	480	110	91	22	10
Brassica napus	5300	5600	3200	1700	1400	30	25	36	42	7
Brassica napus	5400	5300	2900	1800	1400	31	30	30	30	6
Carduus nutans	2700	2900	1500	1500	560	28	48	21	9	9
Carthamus lanatus	3100	3300	1800	1500	420	42	38	40	7	11
Casuarina littoralis	3400	1400	1200	1100	230	290	28	18	25	9
Centaurea solstitalis	3400	3600	2200	1500	500	58	100	35	10	19
Chrondrilla juncea	2200	2100	1400	1100	250	69	30	26	6	5
Cirsium vulgare	2800	3000	1600	1700	420	31	39	26	11	15
Corymbia maculata	6200	4500	2700	740	720	91	51	90	110	40
Corymbia maculata	6000	4800	2900	610	710	130	48	77	79	42
Corymbia maculata	5600	4200	2800	680	710	97	45	58	63	42
Corymbia maculata	6500	4500	2800	740	750	96	49	85	100	39
Echium plantagineum	5100	7200	3100	970	690	49	97	72	25	5

Table 7.6 cont.

Species	K	P	S	Ca	Mg	Na	Fe	Zn	Mn	Cu
Echium plantagineum	5300	7100	3200	1100	690	58	63	64	23	6
Echium plantagineum	5600	7800	3200	1100	730	67	67	72	25	5
Echium plantagineum	5400	7300	3200	890	690	110	30	68	24	5
Echium plantagineum	5700	8000	3300	1100	740	71	63	75	27	5
Echium plantagineum	5500	7200	3000	970	650	51	38	62	25	6
Echium plantagineum	5500	7300	3000	960	640	51	38	64	26	7
Echium plantagineum	5500	7400	3100	1000	690	70	140	340	26	5
Echium plantagineum	5500	7400	3100	1000	650	60	56	67	26	5
Eucalyptus albens	4500	4700	2200	3100	740	46	140	58	53	16
Eucalyptus bridgesiana	5100	4100	2200	1000	500	20	73	80	51	17
Eucalyptus bridgesiana	5000	4200	2300	1000	550	31	90	62	45	16
Eucalyptus bridgesiana	5400	4400	2400	940	530	24	64	55	46	16
Eucalyptus camaldulensis	5300	4700	2400	1000	740	86	110	64	40	19
Eucalyptus fastigata	5600	4300	2300	790	530	39	61	62	60	14
Eucalyptus macrorhyncha	5300	4400	2400	1100	550	16	120	58	62	13
Eucalyptus punctata	6000	5400	3700	940	720	340	520	120	46	30
Eucalyptus robusta	4900	4300	2700	890	540	21	66	65	28	22
Eucalyptus saligna	5300	4700	2500	990	680	92	60	64	38	20
Eucalyptus viminalis	4900	4400	2300	890	520	40	63	58	77	15

Table 7.6 cont.

Species	K	P	S	Ca	Mg	Na	Fe	Zn	Mn	Cu
Fagopyrum esculentum	6800	4800	1100	1800	2700	34	51	17	20	5
Helianthus annuus	2900	2500	1600	1400	500	46	40	37	12	10
Hypochoeris radicata	2500	2100	1400	1000	260	73	16	20	9	5
Hypochoeris radicata	2300	2000	1400	1000	220	160	31	20	6	4
Hypochoeris radicata	2500	2100	1400	1000	260	220	16	20	5	5
Lavandula spp.	2800	2800	1800	1600	270	89	14	16	15	11
Prunus dulcis	8200	4800	2500	990	670	45	84	40	14	8
Rapistrum rugosum	5500	4900	3200	1900	1300	45	49	29	12	7
Salix fragilis	3700	4000	1400	1500	1000	33	41	35	88	3
Sisymbrium officinale	5100	4700	3200	1900	1200	53	42	41	21	5
Trifolium balansae	6800	5200	2100	1100	690	38	94	36	28	9
Ulex europaeus	5700	5900	2600	1100	1100	66	46	73	23	7
Zea mays	4900	3700	1800	580	740	24	26	48	14	4
Mean	5530	4600	2378	1146.4	716	82.02	67.16	58.28	32.68	12.4
Minimum	2200	1400	1100	360	220	16	14	16	5	3
Maximum	38000	8000	3700	3100	2700	480	520	340	110	42
Standard error	690.33	236.33	97.99	64.278	55.79	12.02	10.2	6.67	3.56	1.45

DISCUSSION

Pollen collections

The mixture of pollen pellets from a variety of floral species could assist a honey bee colony in overcoming any significant compound deficiency, particularly with amino acids. Beekeepers should consider the chemical composition of pollens and their impact on honey bees more carefully when pollen from only one floral source is available for a number of brood cycles.

Crude protein

Pollens with crude protein levels less than 20% are considered to be below the minimum level to sustain breeding and development of a honey bee colony. Kleinschmidt *et al.* (1974) suggested that the digestive capacity of honey bees limited protein intake, and pollens containing less than 20% crude protein did not satisfy a colony's nutritional requirements to the extent that colony population growth cannot be sustained, as compared to pollen with more than 25% protein. Higher CP% levels seem to satisfy the nutritional requirements of honey bees for amino acids and protein.

Based on the CP% as it relates to pollen quality stated by Kleinschmidt *et al.* (1974), pollen sources are able to be divided into three general categories: <20% poor, 20-25% average and >25% excellent CP%. The pollen samples chemically analysed are as follows according to the three categories, listing the botanical name (common name) average CP%, and any deficient amino acid identified. Other published references of CP% of the same species are also tabled. These were obtained from one or more of the following references: ([D]Kleinschmidt and Kondos 1976, [E] Rayner and Langridge 1985, [F] Muss 1987, [G] Stace 1996a).

Excellent quality pollens: *Echium vulgare* (Viper's bugloss) 34.9%: *Lupinus angustifolius* (Lupin) 34.2%; 32.6%[E], 28%[F]: *Banksia serrata* (Saw banksia) 33.3%, Iso.; 31.2%[F]: *E. plantagineum* (Paterson's curse) av. 33% (n=63); av. 35.2%[E] (n=2), 31.4%[F], 30.8[G], 33.3%: *Eucalyptus sclerophylla* (Scribbly gum) 29.7%, Iso.: *E. globoidea* (White stringybark) 29.4%, Iso.: *E. blakelyi* (Blakely's red gum) 28.8%, Iso.; 24.3%[F], 22.4%[G], 25.1%, 26.4%: *B. ericifolia* (Heath-leaved banksia) 28.6%, Iso.;

30.1%[G], 30.3%, 31.5%, 31.8%: *Corymbia maculata* (Spotted gum) 28.5%, Iso.; 33.3%[D], 24.7%[G], 26.8%, 27.3%, 28.8%, 31.4%: *Ulex europaeus* (Gorse) 28.4%; 16.5%[F]: *E. saligna* (Sydney blue gum) 27.6%, Meth. Iso.: *E. punctata* (Grey gum) 27.3%, Iso.: *C. gummifera* (Red bloodwood) 26.9%: *E. socialis* (Christmas mallee) 26.6, Iso.: *E. mannifera* (Brittle gum) 26.2%, Iso.: *Pyrus communis* (Pear) 26.2%: *Trifolium repens* (White clover) 25.9%; 24.7%[E], 25.1%[F], 25.6%, 22.5%[G], 22.6%, 23.1%, 24.9%, 25.4%: *T. balansae* (Balansa clover) 25.3%: *E. longifolia* (Woollybutt) 25.2%, Iso.: *Prunus dulcis* (Almond) 25.1%; 30.7%[E], 23.3%[F], 25.5%.

Average quality pollens: *Acacia doratoxylon* (Currawong wattle) 24.9%, Iso.: *E. macrorhyncha* (Red stringybark) 24.9%, Iso.; 30%[E], 23.4%[F], 23.2%[G], 23.4%: *A. longifolia* (Sydney golden wattle) 24.6%: *Vicia faba* (Faba bean) 24.4% ; 22.3%[G], 24.1%: *E. camaldulensis* (River red gum) 24.1%; 25.8%[D], av. 26.5%[E] (n=3), 21.9%[F]: *V. sativa* (Vetch) 24%: *Brassica napus* (Canola) 23.8%; 27.1%[E], 10.6%[F], 23.2%[G],24.9%: *E. bridgesiana* (Apple box) 23.8%, Iso.: *Acacia* spp. (Wattle) 23.8%: *E. viminalis* (Manna gum) 23.7%; 21.3%[F]: *E. microcarpa* (Grey box) 23.6%, Iso.; 25%[D], 23.3%[E], 25%[F]: *E. delegatensis* (Alpine ash) 23%: *Chondrilla juncea* (Skeleton weed) 22.8%: *Rapistrum rugosum* (Turnip weed) 22.7% ; 25-29.2%[D], 24.4%[G] ,25.3%: *E. robusta* (Swamp mahogany) 22.6%: *Asphodelus fistulosus* (Onion weed) 22.5%; 14%[F]: *E. albens* (White box) 22.5%, Iso.; 20.6%[D], 24.3%,16.3%[G], 17.7%, 17.9%, 17.9%, 19.2%, 19.5%, 20.1%: *E. polyanthemos* (Red box) 22.4%, Iso.: *Sisymbrium officinale* (Hedge mustard) 22.2%: *Angophora floribunda* (Rough-barked apple) 22.2%: *Salix discolour* (Pussy willow) 21.9%: *A. suaveolens* (Sweet scented wattle) 21.7%, Iso.: *E. dumosa* (White mallee) 21.4%, Iso.; 24.8%[F]: Papilionaceae (Pea flower) 21.5%, Iso.: *Centaurea solstitialis* (Yellow burr) 20.6%: *E. fibrosa* (Red ironbark) 20.5%.

Poor quality pollens: *Lavandula* spp. (Lavender) 19.4%, Iso.: *Citrus* spp. (Citrus) 18.5%: *Hakea sericea* (Silky hakea) 18.4%, Iso.: *Carthamus lanatus* (Saffron thistle) 18.1%; 18.7%[G], 22.4%, 26.4%: *Arctotheca calendula* (Capeweed) 17.3%, Iso.; 21%[E] , 16.8%[F]: *Cirsium vulgare* (Black thistle) 17%; 31.8%[D], 18.3%[F]: *Hypochoeris radicata* (Flatweed) 15.9%, Val. Iso.; av.18.4%[E] (n=3), 15.7%[F](n=4), 13.6%[G], 15.7%, 16.5%, 19.1%: *Caduus nutans* (Nodding thistle) 15.1%: *Salix fragilis* (Crack willow) 15%, Iso.: *Zea mays* (Maize) 14.9%; 14-15%[G]: *Vaccinium* spp. (Blueberry) 13.9%: *Helianthus annuus* (Sunflower) 13.4% ; 18.5[D], 17.6%[E], 15%[F]: *Casuarina littoralis* (Black she-oak) 12.5%, Val. Iso.; 13.6[D], 11.3%[G], 13.9%, 17.3%: *Senecio madagascariensis* (Fireweed)

12.4%, Iso.; 11.8%[G], 12.7%, 13.3%, 15.2%, 17.3%: *Fagopyrum esculentum* (Buckwheat) 11.4%.

Pollen collections from the same species exhibited some degree of variation of crude protein levels. Most of this variation can be considered acceptable for the purposes of this study as the range of this variation still places the pollen samples from the same species into one of the three categories suitable for beekeepers to generalise on the nutritional merit of each pollen source. Provided with the data from 61 *Echium plantagineum* pollen samples, a single sample of pollen from a species does not provide enough evidence to comfortably state that any given species will always be the same protein value.

Of some concern was the CP% for two pollens reported by Muss (1987) which were substantially lower than the levels found in this research. Pollen from *Ulex europaeus* were reported as 16.5% CP and *Brassica napus* as 10% CP when data from this research indicated substantially higher CP% levels of 28.4% and 23.8% respectively. The CP% for *Cirsium vulgare* (31.8%) as reported by Kleinschmidt and Kondos (1977) was well above the crude protein levels found in this research (16.1%, 17.3%, 17.6%) which were similar to that reported by Muss (1987) of 18.3%. These results demonstrate that some published data may be incorrect or that a large variation may exist within the few samples so far analysed for these species.

The results provide a degree of evidence that pollen from species within the same genus can exhibit similar crude protein levels and thus will probably provide similar nutrition to honey bees. This is supported by the similarity of two species of *Banksia* and *Echium*, both regarded as excellent quality pollens, two *Trifolium* species, both above average, two *Vicia* species and four *Acacia* species, which are average quality pollens.

Amino acids

Isoleucine was the most frequently limiting amino acid. A total of 66 (38%) samples had levels of isoleucine below the desired 4g/16g N level (deGroot 1953). Only two other amino acids, valine and methionine, were recorded below desirable levels. Eleven pollens (5.6%) had valine below the optimal level of 4g/16g N, and two pollens (1%) *Hypochoeris radicata* and *Eucalyptus saligna* with methionine below the ideal level of

1.5 g/16g N. The *E. saligna* pollen was also deficient in isoleucine. Of the nine *H. radicata* samples, four were deficient in both valine and isoleucine, and four deficient in isoleucine only. *Casuarina littoralis, H. radicata, Chondrilla juncea, Acacia suaveolens, Salix fragilis* and *Sisymbrium officinale*, which were deficient in valine, were also deficient in isoleucine.

Of the 41 samples of pollen identified as originating from *Eucalyptus*, or the related species *Corymbia* and *Angophora*, 29 samples (71%) had isoleucine below 4g/16g N. Isoleucine appeared to be consistently at low levels in many samples of pollen particularly the *Eucalyptus* species which was consistent with research by Kleinschmidt and Kondos (1977), Rayner and Langridge (1985), Muss (1987) and Day *et al.* (1990). The results of this study indicate that most of the essential amino acids in honey bee collected pollen samples were at levels sufficient to meet honey bee nutritional requirements outlined by deGroot (1953). If pollen was high in crude protein and significant quantities were gathered, then consumption of greater volumes of pollen may alleviate any minor amino acid deficiency. However, if the crude protein levels were low or the quantities of pollen gathered were low, then pollens with low levels of isoleucine may inhibit the nutritional balance within the colony, and a reduction in brood area and population may result.

Variation in laboratory technique

The variation of proline and lysine for the same pollen samples within Laboratory 2 (Table 7.3) is of little consequence in the context of this study for both amino acids are not considered essential for honey bee nutritional requirements (deGroot 1953). The discrepancies between each laboratory (Table 7.4) for cystine and methionine is also problematic as both amino acids traditionally show the most variation noted by Rayner and Kerr (1996) in their comparison study of five Australian laboratories. Cystine is not an essential amino acid required by honey bees and only two samples tested (1%) indicated levels of methionine below that stated by deGroot (1953), indicating that deficiencies of this amino acid are probably uncommon. The discrepancies between the laboratories for CP% are harder to dismiss, even so the results show a significant range for CP% within each species and the variation between laboratories is not that extreme that the nutritional category of pollen for each species can't be determined.

Variability of CP% and amino acid content for *Echium plantagineum* pollen

Differences between years for amino acids and crude protein content could be as a result of differences in analytical procedure of the two chemistry laboratories used to test the samples. This is supported by Table 7.4, indicating the differences observed between the five samples measured by both laboratories. The evidence to indicate that there are variations in the chemistry of honey bee-collected pollen between geographic locations is stronger than the evidence to suggest differences between years.

Interpretation of data on the crude protein or amino acid content of honey bee-collected pollens should consider possible discrepancies between laboratory providers, chemical analysis locational variance and, to a lesser degree, year (seasonal) effect. Multiple samples are required and preferably across a number of different collection sites to obtain a nutritional value as a source of pollen for honey bees of each floral species.

Fat

The results provide a useful set of data to identify pollens from species with high levels of lipids (fats). The evidence suggests some degree of similarity in lipid content within botanical families. The variability between samples of the same species was of some concern, although the accuracy of the chemistry analysis used to determine total fat content was reduced at lower lipid levels (Kerr 1998, pers. com. Senior Chemist, State Chemistry Laboratory, Werribee, Victoria). A variation in total lipid content up to one percent may be a factor of the reduced accuracy of the chemical analysis when measuring such low volumes of lipids in a substance, this may explain the 0% readings for *Eucalyptus macrorhyncha*. The range of lipid levels for *Echium plantagineum* pollen provided evidence of variation within a species, although variation in lipid levels may have occurred due to differences between laboratory methods.

Pollens from mixed collections may have been contaminated, e.g. *Hypochoeris radicata* pollen was observed to have globules of oil on the surface of the pollen coat, similar globules of oil on the exterior of pollen coats were found by Manning (2001) for *Taraxacum officinale.* Oil from pollens displaying this characteristic may leak onto pollen pellets of other species in the pollen trap and storage container, artificially increasing the fat content of those pollens.

There were few published lipid levels of bee collected pollen to provide evidence of the general authenticity of the results through comparisons. Manning and Harvey (2002) tested six eucalypt pollens and found lipid levels varied from 0.6 to 1.9% which was within the range of the 19 species of eucalypts tested in this research, i.e., 0 to 4.6%, mean 1.8%. They also reported on three other species which were close to the levels found in this research: *Arctotheca calendula* 2.1%, *Brassica napus* 5.9%, and *Lupinus* species 3.0%.

The principal nutritional qualities derived from pollens with high lipid content may be due to this lipid content rather than the protein level. Pollen from species showing high volume and frequency in pollen traps indicate the abundance of these species in the field and/or attractiveness to foraging honey bees. The pollens noted to be particularly attractive to foraging honey bees included *Brassica napus* (mean 6%, n=5), *Hypochoeris radicata* (mean 7.2%, n=9), *Rapistrum rugosum* (mean 6%, n = 5) and *Sisymbrium officinale* (mean 5.8%, n = 3), all with relatively high lipid contents. Of interest, all of these species expressed low protein levels (CP%) *Brassica napus* 23.8%, *Hypochoeris radicata* 15.9%, *Rapistrum rugosum* 22.7% and *Sisymbrium officinale* 22.2%.

The lipid concentrations stated by other researchers (Todd and Bretherick 1942; Youssef *et al.* 1978; Singh *et al.* 1999) were generally much higher than Manning and Harvey (2002) and the data presented in this research. This may be due to preparation of the sample as Scott and Strohl (1962) found that petroleum ether extracted 1.6% of lipids from *Pinus taeda* pollen when whole pollen was placed in the solvent, whereas after a sample of the same pollen was ground, crushing the pollen walls, the same solvent extraction method yielded 6.1% lipids. Further examples of the effect of milling pollen are cited by Manning (2001) for *Brassica napus* increasing the lipid levels from 9.8% to 21.9% and 9.3% to 25.4%. Whether the milling represents the action of the honey bee digestive process is not known, thus at this stage of our understanding of lipids in pollens and the impact on honey bee nutrition we can only be observatory. There can be no doubt that the lipid content of pollens directly impacts on the attractiveness of pollens from various floral species to foraging honey bees and that lipids are most likely to be an essential nutritional component of a honey bee diet.

This research provides one of the largest data sets for lipids in honey bee collected pollens for 61 floral species. Further research should analyse the components of the fat content of pollen profiling the fatty acids of the more attractive pollen sources and thus provide further information to assist in the development of a complete artificial food for honey bees.

Minerals

The results showed a high degree of variability in the concentration of each mineral contained in pollen pellets. Macro elements K, P and S were dominant, followed by Ca, Mg, Na, Cu, Fe, Mn and Zn were found in lesser amounts. Of all species, *Asphodelus fistulosus* had an extremely high concentration of K at 38,000 mg/kg, well in excess of the next highest value of 8,200 mg/kg for K in *Prunus dulcis*. *Asphodelus fistulosus* pollen appears to be readily collected by honey bees, however, the implications for honey bee nutrition or health are not known. Its high concentration of K has parallels with *Allium cepah* (onion) nectar which frequently expresses a high K level when compared to nectar from other sources (Waller *et al.* 1972). Hagler (1990) found onion cultivars with high levels of K to be repellent, while onion cultivars with low K were more attractive to nectar gathering honey bees. It is possible that high K levels may be tolerated in pollen but not in nectar.

It is believed that the pollen pellets transported by honey bees are moistened with sweet liquid (nectar). The possible addition of minerals to pollen from this process is unknown and may influence some of the results. The mineral content is generally greater with darker-coloured honey than with lighter-coloured honey (Petrov 1970), although the total concentrations of various minerals in honey are generally well below the concentrations of elements recorded in pollen pellets. The results from comparing the mineral contents between nectar and pollen pellets indicate that for most of the elements, pollen pellets are the dominant source (Table 7.7). Although there may be some influence from nectar on the total dietary intake of minerals, it is probably not significant.

Table 7.7 Comparison of mineral constituents (mg/kg) of honey and pollen (Petrov 1970).

Element	Mean concentration (mg/kg)		
	Pollen	Dark Australian honey	Light Australian honey
Ca	1146	227	107
Cu	12	1	1
Fe	67	-	-
K	5530	1241	441
Mg	716	132	40
Mn	33	10	1
Na	82	23	251
P	4600	123	129
S	2378	-	-
Zn	58	2	3

There is little published data on the mineral content of pollen pellets. Thus, comparison of data with other published research is only possible for a few species. *Zea mays* pollen was tested by Nation and Robinson (1971) for K, Na, Ca, Mg, Cu, Fe, Mn and Zn where concentrations of Cu and Fe were considerably higher, 31.9 and 148 mg/kg, respectively, than for those collected from southern NSW (4 and 26 mg/kg, respectively). Manning (2000) tested six species of eucalypts in Western Australia for the following 10 elements: boron (B), Cu, Fe, Mn, Zn, P, K, Mg, Ca and S. The mean concentration of Fe (118 mg/kg) for Western Australia eucalypt pollen pellets was much higher than that (67 mg/kg) found for southern NSW. The results for all other minerals in Western Australia fell within the range found in NSW. Todd and Bretherick (1942) published mineral contents (K, P, Ca, Mg and Fe) of pollen pellets as a percentage of total ash for 34 species. They reported greater concentrations of Mg in their research, ranging from 600 to 3,800 mg/kg than the Mg levels in the 50 pollen samples analysed for this research.

It is known that problems do exist with trace elements in the livestock industries and that they can have a significant impact on disease resistance and general productivity in animal production enterprises. Although it is not possible to compare the mineral requirements, either toxicities or deficiencies, between vertebrates such as sheep and cattle, and honey bees, it is possible that similar issues with mineral toxicities or deficiencies occur with honey bee nutrition. The range of mineral concentrations presented should help formulate mineral dietary additives to artificial pollen supplements in order to maximise brood rearing and maintain or increase the long-term honey-gathering potential of honey bee colonies.

CHAPTER 8

GENERAL DISCUSSION

INTRODUCTION

The primary purpose of the study was to identify the principal floral species of importance to New South Wales (NSW) beekeepers. The study has largely achieved this goal in relation to identifying the most important floral species responsible for honey production in the State and has made considerable progress in identifying floral species of importance for their pollen rewards and nutritional contribution to honey bees.

This chapter will summarise the findings of the study, beginning from Chapter 2 through to Chapter 7. A comparison of the information from each source will be provided to value the relative merits of each technique as a source of data to answer the primary question: What are the principal floral species of importance to NSW beekeepers? The basis on which one is able to determine the relative importance of each species has been discussed in earlier chapters, i.e., whether greater or lesser value is placed on nectar or pollen production, and what constitutes value in pollen - quality or quantity.

Chapter 1 briefly discusses the NSW beekeeping industry, the nutritional requirements of honey bees and the threats to the floral species that provide the principal resource for the commercial beekeeping industry. The case study in Chapter 2 provides an example of a commercial beekeeping business in NSW and the floral species of importance to its success. The literature review (Chapter 3) indicates to the reader that not all floral species are the same in relation to their flowering phenology, and briefly covers the parameters determining high and low quality pollens.

The surveys of NSW beekeepers (Chapters 4 and 5) are essentially a summary of the accumulation of data provided by beekeepers such as the one in Chapter 2. These studies are, in essence, a collection of anecdotal data from individuals who rely on their understanding of the floral rewards on offer from the floral species within their operational range.

The honey delivery data in Chapter 6 provides a quantifiable figure that can be used to ascertain the exact monetary value of various floral species based on their nectar production, measured by yields of honey. The chemical analysis of honey bee-collected pollens (Chapter 7) assists in quantifying the value of 51 floral species as a source of pollen, providing a suitability rating as to their relative benefits to honey bees. By doing so, this chapter assists in rating floral species along with Chapters 4 and 5 as to the general worth of individual species as a source of pollen.

SUMMARY OF RESULTS

Chapter 2: The study of one commercial beekeeper's preference for specific floral resources provides an indication of how a study of the primary floral resources over a larger number of beekeepers might take place. The data provided by Des Cannon demonstrates that some species are targeted every year, whereas other species — mainly the eucalypts — are targeted on a two year, or greater, time scale. The regularity of the usage of certain species, particularly *Brassica napus* and *Echium plantagineum* in the spring period nearly every year provides strong evidence for their worth over time in this beekeeping operation. The data also provides an indication that for a beekeeper to be reliant on commercial beekeeping as their main income, he/she must operate sufficient numbers of hives to obtain a desirable net income. In Des Cannon's case, this figure was approximately 600 hives.

Chapter 3: The information on the flowering phenology of melliferous flora within the Australian context is very limited. The factors said to affect nectar production and presumably pollen production were many. The main factors identified and discussed were hereditability, time of day, temperature, light radiation, rainfall, soil moisture, and soil fertility, all of which appear to influence each species in potentially different ways. The added benefit of studying nectar and pollen producing floral species was the potential to use this information to help in the study of native nectarivorous fauna. The extent of the literature on this subject was also limited.

The flowering phenology of melliferous flora has largely not been studied. Issues such as inherent flowering pattern, tree age in relation to flowering frequency, flower bud initiation triggers, and frequency of flowering events are all poorly studied. The quickest method of obtaining information on many of these subjects, including potential nectar and pollen yields possible from each melliferous species, was deemed to be by surveying beekeepers. This group of persons are probably the most knowledgeable on the subject due to decades of observation and their reliance on the success of these observations to predict nectar flows and manage colonies to target these nectar flows.

Chapter 4: The 81% response for this study was excellent given the, at times, sensitive nature of the information provided by the respondents and the general reluctance of a large proportion of the beekeeping population to divulge information, under the fear that it will lead to increased competition for floral resources in their operational range. A total of 227 floral species were identified in the study as having some value to honey bees, 51 of which were mentioned by more than 20 beekeepers, providing a core list of primary melliferous species for the NSW beekeeping industry.

Spatially, the 51 species identified have a fairly extensive distribution, adding weight to their overall value as melliferous resources. The flowering period data provided, in some cases, probably relates to the frequency the species is accessed by beekeepers and not necessarily the frequency of flowering. Although, the greater the number of beekeepers who access any given floral resource, the more likely the species concerned will have reasonably reliable nectar and pollen rewards. Species that are relatively abundant and reasonably reliable in the provision of their floral rewards will have a greater utilisation over time by beekeepers. Conversely, species that may flower with the same frequency but are not as reliable for nectar, would not be targeted on as regular a basis. To ascertain the floral rewards this survey focused on the expected honey yields/hive and an arbitrary value for pollen. Both measures, particularly when combined with the number of sites and frequency of use, provide floral species comparisons with the results in Chapters 5, 6 and 7. The study provided a list of the most important floral species for beekeeping interests in NSW. However, it must be emphasised that this is not a comprehensive list as species at a local level will be important to individual beekeeping operations but do not necessarily appear in a statewide study.

Chapter 5: This survey of beekeepers utilising the State forests of NSW was similar in design to the survey used in Chapter 4. The results obtained for the State forest surveys were similar in identifying the principal floral species of significant importance to commercial beekeepers in NSW.

The value of *Eucalyptus* and *Corymbia* species to beekeepers was supported strongly in this study. An interesting outcome of the study was the number of apiary sites on private property adjacent to State forests, directly accessing the floral species occurring within State forests.

Chapter 6: The honey delivery data from Capilano Honey Limited provided valuable information in enabling the identification of the most important floral species to NSW beekeepers. Eucalypts and related species were the most important genus, contributing 67% of the total volume of honey delivered over the eight year period. Even so, the single most important species was *Echium plantagineum* which accounted for 18% of the annual honey deliveries from 1991 to 1996. The honey delivered for each species annually varied significantly from year to year, even for species that have an identified annual flowering cycle, e.g., honey delivered from *Echium plantagineum* in 1994 was 839,030 kg, whereas in 1996 it reached 2,870,121 kg.

Chapter 7: The chemical analysis of 177 honey bee-collected pollen samples belonging to 61 floral species provided data to categorise these pollens according to nutritional quality parameters. Pollens from 15 species were regarded as low in quality, 26 species were regarded as average, and 20 species were regarded as high quality when the CP% was used as a measure of quality. A total of 61 samples of *Echium plantagineum* pollen, collected over three years from 30 locations were analysed. There was evidence of locational differences in the chemical composition of pollens collected by honey bees and, to a lesser extent, evidence of year differences. The amino acid, isoleucine, was found to be lacking in 66 samples (38%) of pollen, particularly the eucalypts (71%). This meant that colonies would be required to consume greater volumes of the pollens experiencing an imbalance in the amino acid ratios, as described by deGroot (1953).

The results for pollens collected from the same genus demonstrated similar chemical profiles, indicating that generalisations may be possible with many species as to what their nutritional contribution to honey bees might be once a satisfactory number of samples had been tested for any species within the genus. Even though this study represented the largest number of honey bee-collected pollens chemically analysed to date, sufficient information was not available to categorise all floral species in NSW recognised by beekeepers according to quality parameters. The study did not look at the volume of pollen collected by honey bees, which would assist in determining the worth of a floral species, as a provider of pollen to colonies. The value of a pollen source to a colony is a function of its quality and the quantity made available by the floral species.

The use of CP% as a measure of pollen quality is currently accepted by beekeepers (Kleinschmidt and Kondos 1976, 1979; Stace 1996a). The results confer with this concept in the majority of cases, although beekeepers' perception of quality in the field may also be influenced by the larger volume of pollen available from some species and the abundance of other sources of pollen at a time of year when honey bees have limited choice.

Field observations suggest that pollens high in fat content are readily collected by honey bees, yet their dietary impact is not known. The pollens originating from floral species low in CP% yet high in fat content should not be dismissed as low quality. Likewise the role of minerals in honey bee nutrition is largely unknown, yet the data indicated some floral sources with extremely high levels of certain elements. Toxicities and deficiencies may occur from time to time, but the literature does not indicate that this is a regular event.

At present, given the known nutritional requirements of honey bees, the CP% may be the most economical chemical compound to measure to determine the quality of a pollen source. The amino acids are expensive to measure, and analytical discrepancies between laboratories reduce confidence comparing data from other chemistry providers.

COMPARISONS BETWEEN SOURCES OF DATA

State survey (Chapter 4) and case study (Chapter 2): The case study provided an excellent example of one beekeepers preference for specific floral resources. The weakness of the survey and the case study is that they lack depth in defining what made or influenced the beekeepers decision to move hives onto the stated floral species. A more comprehensive study could be conducted in the future, selecting a number of experienced beekeepers to determine the decision making process why they select one floral species over another. From this, the rules for this process, i.e., selecting one floral source instead of another, could be formulated.

The case study lists the species of primary importance to one beekeeper, whereas in the State survey results, the importance of the case study data is reduced. What is a floral species of primary importance for one beekeeper is not necessarily of significant importance on a State level.

State survey (Chapter 4) and literature review (Chapter 3): The review of literature did not provide a hierarchal list of the primary floral species of importance to commercial beekeepers within NSW. Thus the data collected from beekeepers as a result of the State survey provided the first account of its kind. This data represents their lifetime of experience working honey bees on various flowering events and, as such, is possibly more likely to represent the variability that occurs in nectar yields, flowering period and frequency moreso than most conventional research projects which are often restricted to studying a species over a one to three year period due to funding and time constraints.

The literature provided information on the nectar yielding behaviour of a very small group of floral species. The list of floral species provided by the survey of beekeepers should be considered as a starting point for the study of various floral species, given that it is understood these species are known to yield copious quantities of nectar sufficiently often enough for beekeepers to consider them of primary importance to their business.

State survey (Chapter 4) and State Forest surveys (Chapter 5): The similarities between the lists of melliferous species between the study of beekeepers with apiary occupation permits with State Forests and the full State survey (Chapter 4) are very strong. The State survey (Chapter 4) listed 13 floral species with at least 50% of the total apiary sites in NSW located on State forests. Seven of the 13 floral species were of prime importance in studies specifically on State forests. All six remaining floral species, with 50% of the total apiary sites for these species in NSW located on State Forests (Chapter 4), were either ranked second or third in at least one forestry district.

Chapter 4 lists 27 melliferous species mentioned by 20 or more beekeepers with sites in State forests. Only three of these floral species did not feature in the top three most important floral species for any of the State Forest district studies providing strong support for both studies in identifying the primary melliferous species of importance to the NSW beekeeping industry within this land tenure.

State survey (Chapter 4) and honey delivery data (Chapter 6): The honey receipt data provided strong supporting evidence for the primary floral species identified in the State survey (Chapter 4), where the five most important floral species were *Echium plantagineum, Eucalyptus melliodora, E. paniculata/E. siderophloia, Corymbia maculata/C. varigata* and *Brassica napus*. Two of the other top seven honey production floral species according to honey volume delivered, including *E. albens* and *Lophostemon confertus*, were rated high in the State survey (Chapter 4), placed ninth and eleventh on the list of floral species most mentioned by beekeepers.

The floral species not featured in the State survey, yet strongly rated for honey volume received by Capilano was *E. ochrophloia*. Interpreting the figures provided on the volume of honey delivered per floral species originating from NSW based beekeepers will provide a bias with Queensland flora featured in the data, due to the movement of NSW beekeepers into that State from time to time in pursuit of flowering events. The reverse is true for the southern areas of the State, where Victorian beekeepers would be expected to be harvesting substantial quantities of nectar from species in the Riverina region. This data would not be accounted for by a study of NSW based beekeepers and, as such, would undervalue the floral species that are of importance to beekeeping within NSW, particularly the Riverina region.

With the focus on honey, this accounts for nectar production alone and does not apply any consideration to the value of melliferous species as a source of pollen. Thus in relation to valuing melliferous species, it is valuable but not complete. Also the value of honey purposely kept on the hives by the beekeepers for a food store during winter or drought periods is not accounted for in the data.

State survey (Chapter 4) and chemical composition of pollens (Chapter 7): The primary chemical component for ascertaining quality of honey bee-collected pollen remains the crude protein content, due to the lack of knowledge on honey bee requirements of other chemical compounds. As such, pollens were rated as either excellent, average or poor quality in relation to CP%. A comparison between this rating and the value given to the floral species of most importance to NSW beekeepers in Chapter 4 indicated some concern as to the context of the values beekeepers placed on various floral species as a source of pollen for honey bees.

Of the 51 floral species listed in detail in Chapter 4, identified by beekeepers to be of most importance to them managing honey bees, the pollen from 23 floral species were chemically analysed (Chapter 7). When evaluating these floral species for their crude protein, 10 were excellent, 11 were average, and two were poor quality. The 10 floral species identified to provide excellent "quality" pollens (i.e., high CP%) and the value as a pollen source, as stated by beekeepers in the surveys (Chapter 4) is provided in Table 8.1.

Table 8.1 A comparison between excellent quality pollens (i.e., high CP%) and ratings determined by beekeepers (1–5 poor to excellent).

Floral species	**CP%**	**Rating by beekeepers (1 = poor 5 = excellent)**
Banksia ericifolia	28.6	3.5
Corymbia gummifera	26.9	2.5
C. maculata	28.5 (n = 6)	4.4
Echium plantagineum	32.8 (n = 61)	4.8
E. vulgare	34.9	4.6
Eucalyptus blakelyi	28.8	4.1
E. globoidea	29.4	3.6
E. punctata	27.3	1.8
E. saligna	27.6	3.7
E. socialis	26.6	3.2

Eight species identified by beekeepers as high value pollen sources agree with the chemical analysis rating. The two floral species that are rated average to low *Corymbia gummifera* and *Eucalyptus punctata*. Colonies often dwindle seriously after they have been foraging on the blossom of these floral species (Clemson 1985) and, as such, beekeepers have probably related this dwindling to a poor quality pollen. The high CP% for both species does not support the pollen as being a source of the problems experienced by beekeepers with dwindling colony populations if the CP% is the only criteria for quality. The management of honey bees on these two species requires further investigation to ascertain other possible reasons why the dwindling of the colony populations occur. The 11 species identified to provide average "quality" pollens (i.e., CP from 20–25%) and the value as a pollen source, as stated by beekeepers in Chapter 4 is provided in Table 8.2.

Table 8.2 A comparison between average quality pollens (i.e., CP from 20–25%) and ratings determined by beekeepers (1–5 poor to excellent).

Floral species	**CP%**	**Ratings by beekeepers (1 = poor 5 = excellent)**
Angophora floribunda	22 (n = 3)	4.1
Brassica napus	23.8 (n = 5)	4.3
Centaurea solstitialis	20.6	4.1
Eucalyptus albens	22.5 (n = 4)	3.0
E. bridgesiana	23.8 (n = 6)	4.4
E. camaldulensis	24.1 (n = 2)	4.6
E. fibrosa	20.5	2.1
E. macrorhyncha	24.9 (n = 4)	3.9
E. viminalis	23.7	3.9
Papilionaceae (Peaflower)	20 (n = 3)	3.9
Rapistrum rugosum	22.7 (n = 5)	4.8

Of the 11 species only *E. fibrosa* did not score particularly high by the beekeeper rating system. All other mentioned species have a reputation for providing significant quantities of pollen readily gathered by honey bees (Clemson 1985), whereas *E. fibrosa* is typical of the ironbarks and does not generally provide any significant volume of pollen. It is not unreasonable to assume that beekeepers have rated species in this group according to the volume of pollen collected by honey bees.

It is worth noting that in Chapter 4, *Acacia* species did not rate of major importance, yet four species were analysed for the chemical composition of their pollens, all of which were chemically of average quality. As *Acacias* are a dominant genus in the Australian landscape, it may appear that the value of this group of plants as a source of pollen may have been undervalued by beekeepers in Chapter 4 due to similar flowering periods associated with higher valued nectar producing species.

Two of the floral species that were identified by beekeepers in Chapter 4 of major importance for pollen in NSW, *Arctotheca calendula* and *Hypochoeris radicata*, were poor in quality chemically. There may be a number of explanations for this apparent contradiction in values, including the relative abundance of pollen from these two species, the time of year flowering occurred, and other chemical factors that may be stimulating the colony.

Both species are not considered major sources of nectar for honey bees, but they do have an extensive distribution across NSW. They both commence flowering in the early spring when fresh sources of pollen are of major importance for colonies to enable them to expand in population rapidly. The added attraction of *Hypochoeris radicata* is that it could continue to produce flowers throughout the warmer months when the plant is stimulated due to adequate moisture. Both species have been described as of major importance to honey bees due to the "giant" loads of pollen collected (Clemson 1985). Therefore, the time of year the pollen was made available and its apparent abundance ensure that beekeepers value these two species even though they have fairly low CP levels. One other factor for which there is no defining research, is the attractiveness of both pollens due to their high fat content. Both species exhibit medium to high levels of fat, *Arctotheca calendula* 3.4% and *Hypochoeris radicata* 7.4%. This could be a major contributing reason why honey bees favour these two pollen sources.

It is worth noting that of the 15 floral species which were rated of poor quality due to low CP%, no eucalypts were listed. Only two were indigenous species, three were thistles, and half could be considered as agricultural weeds. The remaining six species could be considered to be of agricultural importance.

PRIMARY FLORAL SPECIES — DISCUSSION

There is a myriad of floral species that could be discussed in relation to their relative importance to honey bees and commercial beekeeping interests in NSW. Six species have been chosen based on the survey results in Chapter 4, being the species that were recorded more than a hundred times by commercial beekeepers. They are:

- *Echium plantagineum* (Paterson's curse)
- *Eucalyptus melliodora* (Yellow box)
- *Eucalyptus paniculata/Eucalyptus siderophloia* (Grey ironbark)
- *Corymbia maculata/Corymbia variegata* (Spotted gum)
- *Brassica napus* (Canola)
- *Eucalyptus macrorhyncha* (Red stringybark)

Echium plantagineum

This species was rated by beekeepers to be the most important melliferous resource in NSW. Sixty percent of the commercial beekeepers rated this species as of significant value for honey and/or pollen. This contrasts with historical reports on the species. Rayment (1934) didn't indicate that the species was of any great significance, stating that the plant "yields honey but hardly sufficient to store much in the supers." Goodacre (1947) said that it only grows in "a few inland beekeeping areas and provides an excellent spring stimulant for brood-rearing." He goes on to say that "a small surplus of fairly good quality, light-coloured honey is produced."

Both these earlier reports did not indicate that *Echium plantagineum* was of major, or even of medium, importance to the beekeeping industry, although since 1934 this species has expanded its geographic range. By 1985 Clemson states that, apart from eucalypts, *Echium* is the most important genus to beekeepers who operate in the Southern and Central Slopes and Tablelands areas of NSW, extending over much of the Western Division. This species has increased in its importance to beekeeping over the intervening 40 years. An enquiry into the biological control of *Echium* species provided specific information on the worth of this species to beekeepers (Oldroyd 1985). In NSW, 45% of honey bee colonies were said to be working *Echium* species. This compares favourable to the data presented in Chapter 4, which indicated that 60% of the beekeepers utilising floral resources within NSW rely on *Echium plantagineum*. Oldroyd (1985) in his report on *Echium plantagineum* stated that "the direct production of honey and beeswax was a relatively small proportion of the national crop (12.5%)." This is not supported by the results presented in Chapters 4 and 6. The honey delivery data provided evidence that *Echium plantagineum* was the single most important melliferous species in NSW. The percentage of honey from this species delivered to

Capilano for the period 1991 to 1996 ranged from 9.6% to 29.7%, with a mean of 18% of the annual honey produced in NSW.

The value of the pollen produced from *Echium plantagineum* has been recognised as of the highest value (Clemson 1985; Oldroyd 1985). Clemson (1985) provides evidence of the enormous quantities of pollen that are collected by bees and even states that "the greatest value of this plant to the apicultural industry is in the preparation of colonies to optimum strength for the main late spring and summer honey flows." Oldroyd (1985) comments on the high quality of *Echium plantagineum* pollen, stating that "the crude protein content of *Echium* pollen is 35.2%, *Banksia ornata* being the only pollen known to exceed *Echium* in this respect." The views of Oldroyd (1985) and Clemson (1985) are supported by the results in Chapters 4 and 7, with survey returns providing one of the highest mean pollen values by beekeepers, and the chemical analysis of 61 *Echium plantagineum* pollen samples providing strong evidence for the very high quality reputation of this pollen with a crude protein ranging from 28.1% to 38.4%. This species can justifiably be given the status of the single most important melliferous floral species flowering annually, providing both extensive quantities of nectar and high quality pollen to honey bee colonies in NSW.

Eucalyptus melliodora

This tree was regarded as "the most popular honey-tree in Australia" by Rayment (1934), being a "prolific bloomer, yielding much honey but little or no pollen." These sentiments still ring true and the research presented in Chapters 4 and 6 supports these very early statements. The volume of honey delivered to Capilano Honey Limited from suppliers based in NSW amounted to the second largest quantity — second to *Echium plantagineum* for the period 1989 to 1996. Goodacre (1947) goes one step further than Rayment in his description of *Eucalyptus melliodora* and its worth to honey bees, describing it as "the best honey tree in the world." However his comments on the pollen worth of the tree reduce its value, stating that "practically no pollen is available from this species" and that "bees have much difficulty in keeping up sufficient brood-rearing in the hives." He continues to indicate that a colony can be so weakened in population that, even though there is an abundance of available nectar, an apiary should be moved to a new locality where a pollen source is readily available.

This tree continued to be an important source of honey to beekeepers. In the mid 1980s, Clemson (1985) indicated that this species, was once regarded as the State's best honey tree in terms of quantity of honey produced, but has suffered a serious reduction in numbers due to land clearing which is impacting on its value to beekeepers. The results from Chapter 4 provide a mean honey yield of 42kg per hive, which is within the range of 30–50 kg expected honey yields reported by Clemson (1985).

Eucalyptus paniculata/Eucalyptus siderophloia

These two species share the common name, Grey ironbark, and were formally referred to as *E. paniculata*. Only recently has this species been divided with *E. siderophloia* having a distribution extending along the North Coast, and *E. paniculata* along the South Coast, with both species over lapping on the Central Coast. For the purposes of discussion, these two species will continue to be treated as one due to their similarity in relation to their value to honey bees. The honey delivery data provided an indication that an excellent honey crop can be harvested every three years from this species, with considerable quantities of honey extracted in intervening years, probably indicating a staggered flowering pattern between forests and possibly within forests.

The mean years between flowering events of 2.6 (Chapter 4) supports the honey delivery data, as stated in Chapter 6. The flowering frequency stated by beekeepers of one to five years between working this species also provides an indication that somewhere on the coast each year between October and January this tree is probably flowering. The flowering event frequency of up to five years, as stated by beekeepers, may be due to responses from tablelands based beekeepers who would only consider moving hives onto the coast if there were no reliable nectar sources available closer to their base, during a similar time frame.

The rating provided by beekeepers for pollen indicated that this species is not a prolific producer of this substance. Thus beekeepers need to carefully consider the nutritional management of colonies before, during and after they have been working *E. paniculata* and *E. siderophloia* for nectar. Access to other floral species which have a better value for the provision of pollen will be of major importance in the management of honey bees. Thus this tree is of major importance as a nectar source, but requires support from other floral species to provide pollen to a colony.

Goodacre (1947) provides some historical information on the various beekeeping points of interest about *E. paniculata*. He claims that the species "is the most valuable ironbark species" for honey production, flowering every third year with "up to 200lb [90kg] of honey per colony extracted." Clemson (1985) supports the earlier comments about this species, stating that it is "the most valuable ironbark to beekeepers on the coast." During favourable conditions, colonies may produce 60 to 80kg of honey per hive. The mean value of honey per hive in Chapter 4 was 54 kg, indicating that Clemson (1985) may have been quoting the better years of production.

This species was strongly represented in the State forests, rating in the top three species for most of the coastal forests. Clemson (1985) indicates that due to its timber properties, being "one of the State's hardest, strongest and most durable timbers, it has been heavily felled in the most accessible areas." This is cause for concern, given the apicultural value of this species for honey production.

Corymbia maculata/C. variegata

This is a very distinct species due to its mottled bark type. *Corymbia maculata* was recently split into two species, with *C. variegata* now the North Coast species. The high beekeeping value associated with this tree is due to a combination of factors including reliable nectar secretion and copious quantities of high quality pollen, all available during late autumn, winter and early spring when very few other floral resources are available to the NSW commercial beekeeper. One of the main values of this tree can be attributed to the high nutrient content of the pollen, with a high crude protein level approaching 30% (Chapter 7). The level of importance placed on pollen by beekeepers in Chapter 4 was also very high with a value of 4.37 out of a potential maximum value of 5.

The mean number of years between honey flows was said to be 4, although some beekeepers in the survey gave up to 10 years between flowering events (Chapter 4). This agrees with Rayment (1934) as having "considerable value to the apiarist," flowering every three years. Clemson (1985) says that "this species is a good honey producer", although 'heavy flows are only experienced every 4 to 10 years with moderate flows every 2 to 4 years'.

Brassica napus

Brassica species generally provide significant quantities of nectar and pollen to foraging honey bees (Crane *et al.* 1984). The main attraction of this species to beekeepers is its reliability. Grown every year across the wheat growing regions of NSW, it produces copious quantities of both nectar and pollen in the early spring period, making it an ideal floral resource on which to increase colony populations in preparation for late spring nectar flows. With 35% of the NSW based beekeepers placing some importance on this floral resource, this species may have more value to the industry as a whole than previously considered. Mean honey yields of 21kg per hive are not excessive but, given the time of year they are obtained, they are highly significant as the honey is probably the first crop extracted in the spring season after the over-wintering period. The quantity of honey delivered to Capilano over the 8 years of data collection place this species as the eighth most significant honey producing plant in the State, although individual eucalypts in many cases were not identified in the honey delivery data.

The mean pollen value attributed by beekeepers of 4.34, out of a potential value of 5, reflects the time of year and the large quantities of pollen gathered, rather than the nutritional value of the pollen. Colonies require large quantities of pollen in early spring to enable the population to expand. The crude protein levels ranged from 22.1 to 26.1% with all the essential amino acids required by honey bees at, or close to, the desired levels (Chapter 7). The nutrient value was quite satisfactory for maintaining and stimulating colony expansion. One interesting aspect of the pollen identified in the research was the very high fat levels of the pollen as compared to the means of all the species tested. The implications of these high levels are not understood at present, but future research may indicate further positive aspects of the chemistry of *Brassica napus* pollen as it benefits honey bees.

Eucalyptus macrorhyncha

This species is an autumn flowering eucalypt with a distribution extending across the Northern, Central and Southern Tablelands of NSW. It possibly obtains its ranking in the survey results (Chapter 4) due to its relative abundance compared to other autumn flowering species and its widespread distribution and relative accessibility on private property.

The honey delivery data in Chapter 6 was not able to distinguish *E. macrorhyncha* as the source of any honey delivered to Capilano due to the common name usage of "stringybark". Unfortunately this name can apply to 25 separate species, although there is a strong possibility that a large portion of the "stringybark" honey is harvested from *E. macrorhyncha*.

The mean honey yield of 35 kg per hive as reported in Chapter 4, is well below that quoted by Goodacre (1947) 54 kg, and Rayment, 72 kg. Both these authors were probably referring to the higher range of honey yields obtained from this species. Clemson (1985) indicates a reduced level of importance for this species and even states that it is not a reliable honey producer. The data collected in the Forestry surveys (Chapter 5) indicates an average honey crop of 50 kg per hive, equivalent to that stated by Goodacre (1947). This suggests a difference in yields between private property sites and forest sites.

The value of this species as a source of pollen, according to beekeepers in Chapter 4, was high with a rating of 3.9 out of 5. The chemical analysis of four samples of *E. macrorhyncha* pollen with a crude protein range of 22.1% to 26.9% provides some evidence to support this rating. The only limiting factor chemically identifiable with this pollen source was the reduced levels of the amino acid, isoleucine, which may cause some nutritional stress to colonies. Three of the samples tested were just below the levels recommended by deGroot (1953). This may be overcome by the colony increasing its consumption of pollen. Various authors indicate that this species produces moderate to abundant quantities of pollen (Rayment 1934; Clemson 1985). Combined with a reasonable CP% this suggests that *E. macrorhyncha* is of significant importance as a source of pollen.

The length of time between flowering events from Chapter 4 was 3 to 4 years, which is slightly greater than the 3 year period given by Rayment (1934). It is very likely that the main value of this species is in the provision of stored honey and satisfactory volumes of pollen to assist colonies through the winter period when, in many years, they do not have access to fresh nectar or pollen.

FUTURE RESEARCH

A number of questions arise as a result of the research conducted. As the study was wide ranging in its aim to document the floral resources of significant importance to NSW beekeepers, so it provides a multiple number of possible future research directions. The following are nine possibilities for further research attention:

1. Triggers for nectar secretion.

   What are the factors that trigger nectar secretion for the key melliferous species? Why should the same floral species be "more reliable" as a nectar source in one region as compared to another? The honey delivery data in Chapter 6 illustrates the extreme variability of the availability of nectar from a single species such as *Echium plantagineum* which flowers on an annual basis, unlike the eucalypts.

   A clearer understanding of the factors that assist nectar secretion in the key floral species would assist beekeepers in selecting high yielding locations to place hives and be able to predict with a degree of certainty the likely possibility of a nectar flow. There may be genetic factors influencing nectar secretion of the provenances or cultivars of various plant species. Then again there may be a significant genetic variation within a population in relation to nectar production. With the escalation of farm forestry, trees on farms for shelter belts and the regeneration of environmentally degraded areas, selecting melliferous species with a high nectar yielding capacity would not only benefit commercial honey bees but also the native fauna which rely on nectar as a component of their diets.

2. A study focused on *Eucalyptus melliodora* to ascertain the geographic distribution, density of existing trees, age distribution, general health and the native fauna reliance on the species should be considered as research of major national significance. *Eucalyptus melliodora* was identifiable as the second most important floral species for honey production in NSW after *Echium plantagineum.* Even though it probably still retains the status given to it by Rayment (1934) of Australia's most popular honey tree, there is some evidence that its "greatness" is being threatened. Clemson (1985) warns that the reduction in numbers of *Eucalyptus melliodora* trees is having an impact on the overall value of this species to beekeepers. Chapter 4 identified 77% of all apiary sites with access to

E. melliodora to be on private property land tenure, a further 20% of the apiary sites were on adjacent and similarly managed Rural Lands Protection Board's, Travelling Stock Reserves. This represents a very large proportion of the areas on which *E. melliodora* occurs under going similar land management pressures, mainly from grazing livestock and an aging mature tree population.

Species such as *E. melliodora* have sustained considerable pressure from agricultural land clearing, driven by tax incentives in the 1970s. Firewood collectors also heavily favour box and ironbark species. The impacts of grazing animals around the base of trees, livestock camps and the use of fertilisers may all be having a detrimental impact on the abundance and general health of this species. It is likely that the nomadic behaviour of many of the nectar-eating birds in Australia are heavily reliant on *E. melliodora* as a major food source.

On the 15th March 2002, "White box, Yellow box, Blakely's red gum Woodland" were listed as endangered ecological communities under the Threatened Species Conservation Act 1995 by an independent panel of scientists known as the New South Wales Scientific Committee (New South Wales National Parks and Wildlife Service 2002). Even given this recent status, this does not automatically protect *E. melliodora* in all circumstances.

3. *Eucalyptus paniculata* and *E. siderophloia*, known collectively by beekeepers as Grey ironbark, are the most valuable nectar producing trees on the coastal ranges for honey bees, with a wide geographic spread from Queensland to the far South Coast of NSW. A study of this species to determine the influence that the age and maturity has on nectar secretion, both on volume and sugar content, would provide information to determine an individual tree's worth over time. Given the high value placed on this tree by beekeepers due to the prolific nectar available every two or three years, it is likely that it is also a major food source for resident and nomadic native fauna which prefer diets of nectar.

   Currently *E. paniculata/E. siderophloia* is highly favoured for its timber and is regularly logged. A question worth considering is, would the nectar value of this species exceed the timber value over time? Nectar secretion may improve with age, a 20–25 year old tree approaching its peak nectar yielding capacity may also be close to harvest age. If a sound and arguable monetary value were placed on the nectar production over time then this may be economically comparable to its timber worth. In other words, how much is a tree worth — standing for honey production and ecologically speaking for native fauna, or as a timber resource? The economic impact of flying foxes on commercial fruit crops is a result of lack of the animals preferred diet—nectar. The value of nectar is thus of greater importance than the value attributed to commercial beekeeping activity. This thinking may well influence the way the values of the forest resource are perceived by the greater community.

4. The results of this study indicate that the tree *E. macrorhyncha* has been reduced in importance with a history for being an excellent and reliable nectar producing species as indicated in earlier publications. The State Forest surveys indicated a much higher yield of honey per hive as compared to that of the whole State survey, which included data on private and public property. The large percentage of *E. macrorhyncha* apiary sites were found on public property (79%). Similar studies to those suggested for *E. melliodora* could be considered for *E. macrorhyncha*. The disturbance to *E. macrorhyncha* communities by livestock camps, the use of fertilisers and the general health issues of isolated mature trees without an adequate age distribution of the species raises questions as to the health of this species particularly on farm and grazing lands as compared to the reduced disturbance expected in public forests.

5. The tree species *E. camaldulensis* was described by many apiarists in Rayment's (1934) book on profitable honey plants of Australasia as "the finest honey-producing tree in Australasia." This may have been true at the time, through the 1930s, 1940s and 1950s, but in recent decades the species has fallen from grace as a regular and reliable producer of nectar.

   The species still retains a high level of importance but the factors that contributed to its demise are not understood. Some suggestions include lack of regular spring flooding, increased salinity of the available water, or other factors such as increased insect attack on foliage on a more frequent basis. Future research could investigate the validity of these hypotheses.

The triggers for growth and bud initiation need to be understood to determine the factors influencing the size of the honey crops obtained from this species. This tree, given its historic status as a major honey-producing species, was in all probability a major source of nectar for nomadic and resident Australian native fauna. Many of these species may well have relied on *E. camaldulensis* nectar to initiate breeding activity.

6. Key pollen producing floral species as identified in Chapter 4 should be targeted for future pollen collections and chemical analysis. Determining the crude protein and amino acid components of the pollen for these species would assist beekeepers in their management strategies, knowing whether the pollen was of a high quality in relation to crude protein levels or whether it was deficient in one or more amino acids. There is sufficient evidence in the literature to indicate that the nutritional value of pollen relates directly to the management success or otherwise of Australian beekeepers.

   Further research into the components of pollens, particularly the fatty acids, vitamins and minerals, will assist in the understanding of the dietary intake of honey bees. To add maximum value to this research proposal, the actual dietary requirements of honey bees needs to be better informed, and studies along these lines need to determine the function of these dietary components and the desirable intake quantities of each substance.

7. Ultimately this information could be used to design a complete pollen substitute, thus overcoming the dietary deficiencies experienced with some major nectar sources such as *E. melliodora, E. paniculata* and *E. siderophloia*. Colonies could also be managed on complete artificial diets to maintain target populations of field bees to meet specific pollination requirements of commercial flowering crops. Potentially, if a complete pollen substitute was successfully developed and was economically affordable, the whole nature of commercial beekeeping in Australia in regards to the current practice of "Hunter Gatherer" could change.

8. Stocking rates (hives per site) vary only a little as beekeepers place truck loads, usually 100 hives, on any given location. The question remains, what is the standing nectar/pollen production for a given area? Is the maximum honey

production being harvested from this area or is it being under utilised? Knowing this information may assist in also not over stocking any particular area to the detriment of the colony and other species that feed on nectar and pollen.

9. It is evident that beekeepers have accumulated a wealth of knowledge and understanding of the flowering behaviour of nectar and pollen producing plants in their operational range. It is also apparent that this group of people may well be able to assist land managers, policy makers and ecologists in identifying changes in the floral rewards and general reliability of various plant communities to yield nectar and pollen for native fauna if they could be persuaded to impart this information. Beekeepers constantly change their beekeeping management practices to suit the environmental conditions and future prospects. Long-term floral databases originating from beekeeping activities may well provide evidence to indicate changes within our environment.

REFERENCES

Anon. (2004), *Flora online.* Compiled and edited by staff of the national herbarium of New South Wales © 1999-2004 Royal Botanic Gardens and Domain Trust, Sydney Australia. http://plantnet.rbgsyd.nsw.gov.au/

Anderson D (1997), *Disappearing disorder,* The Australasian Beekeeper 99(5), 186-188.

Anderson JME, Graham MF, Bishop AD (1983), *Honeybee and native insect responses to Angophora nectar flow.* University of New South Wales, School of Zoology, unpublished.

Armstrong JA (1979), *Biotic pollination mechanisms in the Australian flora - a review,* New Zealand Journal of Botany 17, 467-508.

Ashton DH (1975), *Studies of flowering behaviour in Eucalyptus regnans F. Muell.,* Australian Journal of Botany 23, 399-411.

Auld BA, Medd RW (1987), *Weeds.* Department of Agriculture New South Wales (Inkata Press: Melbourne).

Australian Honey Board (1990), *Australian Honey Board,* Twenty-seventh Annual Report, 1989-90.

Australian Honey Board (1991), *Australian Honey Board,* Twenty-eighth Annual Report, 1990-91.

Australian Honey Board (1992), *Australian Honey Board,* Twenty-ninth Annual Report, 1991-92.

Barbier E (1963), *Les Lavandes et L'Apiculture dans le sud-est de la France,* Annales De L'Abeille 6(2), 85-159.

Barrett P (1995), *The immigrant bees 1788 to 1898,* A cyclopaedia on the Introduction of European Honey bees into Australia and New Zealand, published by author, Springwood NSW.

Beardsell DV, O'Brien SP, Williams EG, Knox RB, Calder DM (1993), *Reproductive Biology of Australian Myrtaceae,* Australian Journal of Botany 41, 511-526.

Blake ST, Roff C (1988), *Honey Flora of Queensland.* Department of Primary Industries information series Q187015, Queensland Government, Brisbane. Third Edition.

Boland DJ, Brooker MIH, Chippendale GM, Hall N, Hyland BPM, Johnston RD, Kleinig DA, Turner JD (1984), *Forest Trees of Australia,* Fourth edition. CSIRO: Australia.

Bond HW, Brown WL (1979), *The exploitation of floral nectar in Eucalyptus incrassata by honeyeaters and honeybees*, Oecologia 44, 105-111.

Boomsma CD (1981), *Native Trees of South Australia*, Woods and Forest Department, South Australia, Bulletin 19, Second Edition.

Braithwaite LW, Dudzinski ML, Turner J (1983), *Studies on the Arboreal Marsupial Fauna of Eucalypt Forests being harvested for wood pulp at Eden, NSW II Relationship between the fauna density, richness and diversity, and measured variables of the habit*, Australian Wildlife Research 10, 231-247.

Breckwoldt R (1986), *The last stand. Managing Australia's remnant forests and woodlands.* Department of Arts, Heritage and Environment. Australian Government, Canberra.

Brooker MIH, Kleinig DA (1990a), *Field Guide to Eucalypts. South-Eastern Australia,* Volume 1 Inkata: Melbourne and Sydney.

Brooker MIH, Kleinig, DA (1990b), *Field Guide to Eucalypts. South-Western Australia,* Volume 2. Inkata: Melbourne and Sydney.

Caprio JM (1966), *Pattern of plant development in the Western United States* Montana State University, Bozeman Bulletin 607.

Carreck NL (1997), *Changing nectar sources for honeybees in the UK.* Proceedings of the XXXVth International Apicultural Congress of Apimondia, Antwerp, pp 282-286.

Clemson A (1985), *Honey and Pollen Flora* Department of Agriculture, New South Wales. Inkata: Melbourne.

Cocks KD, Dennis C (1978), Apiculture. Chapter 2, 23-30. *Land Use on the South Coast of New South Wales.* A study in methods of acquiring and using information to analyse regional land use options. General editors Austin MP and Cocks KD. Commonwealth Scientific and Industrial Research Organisation, Australia.

Cohen SA, Meys M, Tarvin TL (1989), *The pico tag method - a manual of advanced techniques for amino acid analysis.* Millipore Corporation.

Collins BG (1980), *Seasonal variations in the abundance and food preferences of honeyeaters (Meliphagidae) at Wongamine, Western Australia*, Western Australian Naturalist 14, 207-212.

Corbet SA, Delfosse ES (1984), *Honeybees and the nectar of Echium plantagineum L in south-eastern Australia*, Australian Journal of Ecology 9, 125-139.

Costermans LF (1983), *Native Trees and Shrubs of South-Eastern Australia,* Weldon: Australia.

Crailsheim K, Pabst MA (1988), *Effect of honey with a high mineral content upon the mortality and upon the midgut cells of the honeybee in winter.* Mitteilungen-der-Deutschen-Gesellschaft-fur-Allgemeine-und-Angewandte-Entomologie 6, 125-135.

Crane E (1976), *Honey, A comprehensive survey.* Bee Research Association, Great Britain. London.

Crane E (1990), *Bees and Beekeeping.* Science, Practice and World Resources. Heinemann Newnes Oxford.

Crane E, Walter P, Day R (1984), *Directory of important world honey sources.* International Bee Research Association. London.

Cremer KW, Cromer RN, Florence RG (1978), *Stand establishment in Eucalypts for wood production* (2nd edition) (ed Hillis EW and Brown AG) 81-135.

Dadd RH (1973), *Insect nutrition: current developments and metabolic implications,* Annual Review of Entomology 18, 381-420.

Day S, Beyer R, Mercer A, Ogden S (1990), *The nutrient composition of honey bee-collected pollen in Otago, New Zealand,* Journal of Apicultural Research 29(3), 138-146.

deGroot AP (1953), *Protein and amino acid requirements of the honeybee Apis mellifera.* Physiologia Comparata et d'Ecogia, 3, 201-285.

Doull KM (1974), *Biological and technical factors affecting profitability in beekeeping,* The Australasian Beekeeper 75(7), 163-167.

Eby P (1991), *Seasonal Movements of Grey-headed Flying Foxes, Pteropus poliocephalus (Chiroptera: Pteropodidae), from Two Maternity Camps in Northern New South Wales,* Wildlife Research 18, 547-59.

Eby P (1995), *The biology and management of flying foxes in NSW,* NSW National Parks and Wildlife Service, Species Management Report Number 18.

Eldridge K, Davidson J, Harwood C, van Wyk G (1993), *Eucalypt Domestication and Breeding.* Oxford Science Publications.

Fairley A, Moore P (1989), *Native Plants of the Sydney District - an identification guide.* (Kangaroo Press: New South Wales).

Feldlaufer MF, Lusby WR, Knox DA, Shimanuki H (1993), *Isolation and identification of linoleic acid as an antimicrobial agent from the chalkbrood fungus, Ascosphaera apis,* Apidologie 24, 89-94.

Fogarty R, Somerville DC, Garbin ARP (2000), *Inquiry into beekeeping in urban areas report*, The Government of New South Wales, (unpublished).

Ford HA, Paton DC, Forde N (1979), *Birds as pollinators of Australian plants*, New Zealand Journal of Botany 17, 509-519.

Free JB (1993), *Insect Pollination of Crops*, 2nd Edition. Academic Press, London, Great Britain.

Gary NE (1986), *The Hive and the Honey Bee,* Chapter VII, Activities and Behaviour of Honey Bees. Dadant Publications, Illinois, United States of America.

Gibbs DHM, Muirhead IF (1998), *The economic value and environmental impact of the Australian beekeeping industry*, A report prepared for the Australian Beekeeping Industry.

Gill RA (1989), *The value of pollination services in Australia*, The Australasian Beekeeper, 91(6), 256-274.

Gilmour AR, Cullis BR, Welham SJ, Thomspon R (2002), *ASRenl Reference Manual*, 2nd edition, Release 1.0. NSW Agriculture Biometrical Bulletin 3, NSW Agriculture, Locked Bag, Orange NSW 2800, Australia.

Girnik DV, Cheryatnikova TL, Rusakova TM (1977), *Soil fertilisation and nectar yield of honey plants*, Proceedings of the 26th International Congress in Apiculture, Adelaide (Ed. Prof. Dr Eng. Harnaj) Apimondia: Bucharest, 399-402.

Goldingay RL, (1990), *The foraging behaviour of a nectar feeding marsupial Petaurus australis*, Oecologia, 85, 191-199.

Goodacre WA (1947), *The Honey and Pollen Flora of New South Wales*, New South Wales Department of Agriculture. Government Printer: Sydney.

Grigoryan GA, Stepanyan VA, Markosyan AA, Ganielean SG (1971), *Trace elements in pollen pellets and in the body of bees*, Proceedings of the International Apicultural Congress, Moscow 23, 425.

Gruszka J (1998), *Beekeeping in Western Canada*. Alberta Agriculture, Food and Rural Development. Edmonton, Alberta. pp 31-34.

Gyger HP (1997), *Sources of Honey and Pollen in Regions of Intensive Agriculture in North Western Switzerland*. Proceedings of the XXXVth International Apicultural Congress of Apimondia, Antwerp pp 289.

Hagler JR (1990), *Honeybee (Apis mellifera) response to simulated onion nectars containing variable sugar and potassium concentrations,* Apidologie 21, 115-121.

Harden GJ (2002), *Flora of New South Wales*, Revised Editions Volume 1, 2, 3 and 4. Royal Botanic Gardens, University of New South Wales Press, Sydney.

Haydak MH (1961), *Influence of storage on the nutritive value of pollens for newly emerged honeybees*, American Bee Journal 101, 354-355.

Haydak MH, Dietz A (1972), *Cholesterol, pantothenic acid, pyridoxine and thiamine requirements of honeybees for brood rearing*, Journal of Apicultural Research 1(2), 105–109.

Herbert EWJ (1979), *A new ash mixture for honeybees maintained on a synthetic diet*, Journal of Apiculture Research 18(2), 144-147.

Herbert EW Jr (1992), *Honey bee nutrition*, Chapter 6, 197-233. The Hive and the Honey Bee, Edited by Graham JM. Dadant and Sons, Hamilton, Illinois.

Herbert EW Jr, Shimanuki H (1977), *Brood-rearing capacity of caged honey bees fed synthetic diets*, Journal of Apicultural Research 16(3), 150-153.

Herbert EW Jr, Shimanuki H (1978), *Mineral requirements for brood-rearing by honey bees fed a synthetic diet*, Journal of Apicultural Research 17, 118-122.

Herbert EW Jr, Shimanuki H (1981), *Cholesterol and salt requirements for brood rearing by honey bees fed a pollen substitute*, American Bee Journal (121), 572-574.

Hopper SD, Burbridge AA (1982), *Feeding behaviour or birds and mammals of flowers of Banksia grandis and Eucalyptus angulosa*, Pollination and Evolution, edited by Armstrong JA, Powell JM, Richards AJ, Royal Botanic Gardens, Sydney, 67-75.

Horn H (1985), *The causes of paralysis in honeybees during a honeydew flow (black disease)*. 1. The effect of mineral content in honeydew honeys. Apidologie 16, 139-155.

Horr RZ (1998), *Salt - an important dietary supplement in honeybee nutrition*, American Bee Journal 138, 662.

Hornitzky M, McDonald R, Kleinschmidt G (1993), *Commercial beekeeping in New South Wales*, Honeybee Research and Development Council, Final report.

House HL (1961), *Insect nutrition*, Annual Review of Entomology 6, 13-26.

Howell DJ (1974), *Bats and pollen: physiological aspects of the syndrome of chiropterophily*, Comparative Biochemistry and Physiology 48A, 263-276.

Imdorf A, Bogdanov S, Kilchenmann V, Willie H (1985), *Cement honey in honey super and brood chamber - what then?* Part 2: Does cement honey (honeydew honey) produce a toxic winter feed? Schweizerisch-Bienen-Zeitung 108, 581-590.

Industry Assistance Commission (1985), *Draft report on biological control of echium species (including Paterson's curse/Salvation jane).* Australian Government, Canberra.

Jakobsen HB, Kristjansson K (1994), *Influence of temperature and floret age on nectar secretion in Trifolium repens L*, Annals of Botany 74 (4), 327-334.

Jacobs MR (1955), *Growth habits of the Eucalypts*, Forestry and Timber Bureau. Department of the Interior. Commonwealth of Australia 4031/55.

Johnson LH (1946), *Nectar secretion in clover. Effect of soil and climate on nectar production*, New Zealand Journal of Agriculture 73, 111-112.

Kavanagh RP (1987), Forest phenology and its effect on foraging behaviour and selection of habit by the yellow-bellied glider, *Petaurus australia* Shaw. Australian Wildlife Research 14, 371-384.

Keast A (1968), Seasonal movements in the Australian honeyeaters (*Meliphagidae*) and their ecological significance. The Emu, Journal of the Royal Australasian Ornithologists Union 67(3), 159-209.

Kevan PG, Lee H, Shuel RW (1991), *Sugar ratios in nectars of varieties of canola (Brassica napus)*, Journal of Apicultural Research 30(2), 99-102.

Kleinschmidt GJ (1986), *Nutrition for long life bees*, Research Paper 3.5.7. Published Queensland Agricultural College, Lawes, Gatton. Department of Plant Protection and the Queensland Beekeepers Association.

Kleinschmidt GJ, Kondos AC, Harden J, Turner JW (1974), *Colony management for eucalypt honey flows*, The Australasian Beekeeper 75(11), 261-264.

Kleinschmidt G, Kondos A (1976), *The influence of crude protein levels on colony production*, The Australasian Beekeeper 78, 36-39.

Kleinschmidt G, Kondos A (1977), *The effect of dietary protein on colony performance*, Proceedings of the 26th International Apicultural Congress, Adelaide 357-361.

Kleinschmidt G, Kondos A (1979), *Colony management for low quality pollens*, The Australasian Beekeeper 81, 5-6.

Knox DA, Shimanuki H, Herbert EW (1971), *Diet and the longevity of adult honey bees*, Journal of Economic Entomology, 64, 1415–1416.

Laidlaw HH and Page RE (1996), *Queen rearing and bee breeding.* Wicwas Press, Cheshire, Connecticut, USA.

Law B, Mackowski C, Schoer L, Tweedie T (2000), *Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales*, Austral Ecology 25, 160-178

Law BS (1994), *Banksia nectar and pollen: Dietary items affecting the abundance of the common blossom bat, Syconycteris australis, in south-eastern Australia*, Australian Journal of Ecology 19, 425-434.

Lunden R (1954), *A short introduction to the literature on pollen chemistry*, Svensk Dem. Tidskr 66, 201-213.

Manning R (1992), *Honey production economic value and geographical significance of apiary sites in Western Australia*, Honeybee Research and Development Council Canberra, Final report DAW 3H.

Manning R (2000), *Pollen analysis of six species of eucalypt in Western Australia.* Rural Industries Research and Development Corporation. Project No. DAW-91A.

Manning R (2001), *Fatty acids in pollen: a review of their importance for honey bees*, Bee World 82 (2), 60-75.

Manning R, Harvey M (2002), *Fatty acids in honey bee-collected pollens from six endemic Western Australian eucalypts and the possible significance to the Western Australian beekeeping industry*, Australian Journal of Experimental Agriculture, 42, 217–223.

McFarland DC (1985), *Flowering biology and phenology of Banksia integrifolia and B. spinulosa (Proteaceae) in New England National Park, NSW.* Australian Journal of Botany 33, 705-714.

Mohr NA, Jay SC (1990), *Nectar production of selected cultivars of Brassica campestris L and Brassica napus L*, Journal of Apicultural Research 29(2), 95-100.

Moncur MW (1992), *Effect of low temperature on floral induction of Eucalyptus lansdowneana*, F. Muell et J. Brown subsp. *lansdowneana*, Australian Journal of Botany 40, 157-167.

Morthorpe KJ, Jones WA, Ryan KM, Holtkamp RH (1989), *Pollination efficiency and management of honey bees in lucerne seed production*, Honey Research Council, Final report DAN-5H.

Mullin LJ, Pswarayi I (1990), *Flowering periodicity in provenances of Eucalyptus camaldulensis in Zimbabwe*, Commonwealth Forestry Review 69(1), 69-77.

Muss L (1987), *The nutritional quality of Victorian pollens*, Masters degree thesis, Bendigo College of Advanced Education. Department of Biological and Chemical Sciences.

Nation JL, Robinson FA (1968), *Brood rearing by caged honey bees in response to inositol and certain pollen fractions in their diet,* Annals of the Entomological Society of America 61, 514-517.

Nation JL, Robinson FA (1971), *Concentration of some major and trace elements in honey bees, royal jelly and pollens, determined by atomic absorption spectrophotometry*, Journal of Apicultural Research 10(1), 35-43.

New South Wales National Parks and Wildlife Service (2002), *White box – Yellow box – Blakely's red gum (Box-Gum) Woodland.* Fact-sheet http://www.npws.nsw.gov.au/

Nguyen VN (1999), *Effect of protein nutrition and pollen supplementation of honey bee (Apis mellifera L.), colonies on characteristics of drones with particular reference to sexual maturity*, The Australasian Beekeeper 101, 374-375, 419-425.

Oldroyd B (1985), *Likely impact on the Australian Honey Industry from a reduction in Echium spp.* Appendix E. Draft Report on Biological Control of Echium Species (including Paterson's Curse/Salvation Jane), July 1985 E.1-14.

Petrov V (1970), *Mineral constituents of some Australian honeys as determined by atomic absorption spectrophotometry*, Journal of Apicultural Research, 9, 95–101.

Porter JW (1978), *Relationships between flowering and honey production of Red ironbark, Eucalyptus sideroxylon (A. Cunn.) Benth., and climate in the Bendigo district of Victoria.* Australian Journal of Agricultural Research, 29, 815-829.

Pyke GH (1980), *The foraging behaviour of Australian honeyeaters: a review and some comparisons with humming birds*, Australian Journal of Ecology 5, 343-370.

Pyke GH (1983), *Seasonal pattern of abundance of honeyeaters and their resources in heathland areas near Sydney,* Australian Journal of Ecology 8, 217-233.

Pyke GH (1985), *The relationship between abundances of honeyeaters and their food resources on open forest areas near Sydney,* In 'Birds of Eucalypt Forests and Woodlands", Ecology, Conservation, Management' (eds A. Keast, HF Recher, H Ford and D Saunders), Surrey Beatty and sons, Chipping Norton NSW, 65-77.

Rayment T (1934), *Profitable Honey Plants of Australasia.* Whitcome & Tombs, Melbourne.

Rayner CJ, Langridge DF (1985), *Amino acids in bee collected pollens from Australian indigenous and exotic plants*, Australian Journal of Experimental Agriculture 25, 722-726.

Rayner C, Kerr M (1996), *Amino acid proficiency testing for pig research laboratories.* DAV 108P. Pig Research & Development Corporation, Canberra.

Sawyer R (1988), *Honey identification*, Cardiff Academic Press, Great Britain.

Scott R, Strohl MJ (1962), *Extraction and identification of lipids from loblolly pine pollen*, Phytochemistry, 1, 189–193.

Shuel RW (1986), Chapter VIII, *The Production of Nectar*, The Hive and the Honey Bee. Dadant Publications, USA.

Shuel RW, Shivas JA (1953), *The influence of soil physical condition during the flowering period on nectar production in snapdragon*, Plant Physiology, 28, 645-651.

Singh S, Saini K, Jain KL (1999), *Quantitative comparison of lipids in some pollens and their phagostimulatory effects in honey bees*, Journal of Apicultural Research 38 (1-2), 87-91.

Singh RP, Singh PN (1996), *Amino acid and lipid spectra of larvae of honey bee (Apis cerana Fabr) feeding on mustard pollen*, Apidologie 27, 21-28.

Smith B (1999), *State Forests of NSW, Environmental and Social Values Report 1999/2000*, State Forests of New South Wales, Pennant Hills, NSW.

Somerville D (1997), *Bee Sites & Rural Lands protection Boards in NSW - A Major Resource.* The Australasian Beekeeper Oct 1997. 99 (4), 142-143.

Somerville D (1998a), *Floral resource database*, New South Wales Apiarists Association Newsletter, September-October, 9-12.

Somerville D (1998b), *State Forests — A valuable beekeeping resource*, The Australasian Beekeeper, Sept, 100(3), 96–101.

Somerville D (1999a), *Floral resource database for the NSW Apiary Industry*, Rural Industries Research and Development Corporation, Final report No. 99/174.

Somerville D (1999b), *NSW National Parks & Beekeeping.* The Australasian Beekeeper April 1999, 100 (10), 404-407.

Somerville D (2000a), *Honey bee nutrition and supplementary feeding.* Agnote DAI178, New South Wales Agriculture, Goulburn.

Somerville D (2000b), *Pollen trapping and storage.* Agnote DAI-207 New South Wales Agriculture, Goulburn.

Somerville, DC, Moncur MW (1997), *The Importance of Eucalypt Species for Honey production in NSW, Aust.* Paper for International Apicultural Congress, Antwerp, Belgium, 1-6 Sept 1997.

Somerville D, White B, Rhodes J (2000), *Beekeeping Course 0624.* Open Training and Education Network - Distance Education Unit, Strathfield NSW.

Stace P (1996a), *Protein content and amino-acid profiles of honeybee-collected pollens*, Bees'N Trees Consultants, Lismore NSW.

Stace P (1996b), *The Pilliga Scrub Forests as a Bee Farming Resource; Effect of the proposed Kamilaroi (Pilliga) Wilderness on the NSW Beekeeping Industry.* NSW Agriculture, Wollongbar, February 1996.

Stace P, White E (1994), *The use of isoleucine as a supplement feed for honey bees (Apis mellifera) in Australia*, The Australasian Beekeeper, 96, 159–161.

Standifer LN (1966), *Some lipid constituents of pollens collected by honeybees*, Journal of Apicultural Research 5, 93-98.

Standifer LN (1967), *A comparison of the protein quality of pollens for growth-stimulation of the hypopharyngeal glands and longevity of honey bees, apis mellifera L. (Hymenoptera: Apidae)*, Insectes Sociaux, Paris, 14 (4), 415–426.

State Forests (1996), *Beekeeping & State Forests - An Occasional paper.* State Forests of New South Wales, Sydney, September 1996.

Szabo TI (1982), *Nectar Secretion by 28 varieties and breeder's lines of two species of rapeseed (Brassica napus and B. campestris)*, American Bee Journal 645-647.

Todd FE, Bretherick O (1942), *The composition of pollens*, Journal of Economic Entomology 35(3), 312-337.

Turner JW, Kleinschmidt GJ, Kondos AC, Harden J (1973), *Studies of populations of honey bee colonies foraging on two species of eucalypts*, in "Proceedings of the 1st Australian bee congress 13–26 October 1972", Queensland (Ed. F Smith), p 105–110. (Apimondia Publishing House: Bucharest, Romania.)

Turner V (1982), *Marsupials as pollinators in Australia.* In Armstrong JA, Powell JM, Richards AJ (eds) Pollination and Evolution, Royal Botanic Gardens, Sydney, 55-66.

Van Loon AP (1966), *Investigations in regenerating the Tallowwood-Bluegum forest type*, Forestry Commission of New South Wales, Research Note No. 19.

von Frisch K (1950), *Bees, their vision, chemical senses and language*, Cornell University Press, Ithaca, New York.

Youssef AM, Farag RS, Ewies MA, El-Shakaa SMA (1978), *Chemical studies on pollen collected by honey bees in Giza region Egypt,* Journal of Apicultural Research 17(3), 110-113.

Waller GD, Carpenter EW, Ziehl OA (1972), *Potassium in onion nectar and its probable effect on attractiveness of onion flowers to honey bees.* Journal of American Society of Horticultural Science 97, 535-539.

Wardell G (1982), *European Foulbrood: association with michigan blueberry pollination and control.* Entomology Department, Michigan State Univ. Vii 84.

Warhurst P, Goebel R (1995), *The bee book — beekeeping in the warmer areas of Australia*, (Department of Primary Industries: Brisbane, Qld).

Weatherhead T (1986), *Boxes to bar hives, beekeeping history of Queensland*, Stanthorpe, Queensland.

Winston ML (1992), *The honey bee colony: Life history.* Chapter 3, 73-101. The Hive and the Honey Bee, Edited by Graham JM Dadant and Sons, Hamilton, Illinois.

Winter TS (1975), *Beekeeping in New Zealand.* Bulletin 267 Ministry of Agriculture and Fisheries. Wellington, New Zealand. pp 6-7.

Zimmerman M, Nagy ES, Galloway L (1987), *Nectar dispersion patterns in three Australian plant species*, Australian Journal of Ecology 12, 183-188.

Zherebkin M (1965), *Digestion in bees from weak and strong colonies*, Pchelovodstvo 42, 25-27.

Ziegler KI (1993), *Leatherwood nectar resource management report*, Forests and Forest Industry Council, Tasmania.

PUBLICATIONS AS A RESULT OF STUDY

Refereed Scientific Publications

Somerville DC, Nicol HI (2002), *Mineral content of honeybee collected pollens from southern New South Wales.* Australian Journal of Experimental Agriculture. **42** (8) 1131-1136.

Submitted for publication

Somerville DC, Nicol HI (2005), *Crude protein and amino acid composition of honey bee-collected pollen pellets from south east Australia and a note on laboratory disparity.* (Accepted – Australian Journal of Experimental Agriculture).

Somerville DC, Nicholson D (2005), *The primary melliferous flora and other aspects associated with beekeeping with State Forests of New South Wales as determined by surveying beekeepers.* (Accepted – Australian Forestry).

Somerville DC ( ), *Total fat content of honey bee-collected pollen from south east Australia.* (submitted Australian Journal of Experimental Agriculture).

Somerville DC, Collins D ( ), *Variability of crude protein and amino acid content of honey bee-collected pollen pellets from Echium plantagineum.* (submitted NSW DPI Biometry section for review).

Conferences

Somerville DC (1998), *NSW State Forests, A valuable beekeeping resource.* Inaugural Research Colloquium. 5 February 1998. Australian National University Canberra Forestry. 12.

Somerville DC (2000), *Eucalpytus in Asia: A Beekeeping Resource.* Asian Bees and Beekeeping, Progress of research and development. Proceedings of Fourth Asian Apicultural Association International Conference, Kathmandu, March 23-28, 1998. 218-222.

Somerville DC, Moncur MW (1997), *The importance of Eucalypt species for honey production in New South Wales, Australia.* Paper for XXXVth International Apicultural Congress, Antwerp, Belgium. 1-6 September 1997. 327-331.

Somerville D, Peasley W (2001), *Eucalyptus pollens and their value to honeybee nutrition.* Proceedings of the third AAA Conference on bee research and beekeeping development. Hanoi, Vietnam, 6-10 October 1996. 89-94.

Funding organisation final reports and stand alone publications

Somerville D (1997), *Beekeeping in the Bulahdelah State Forests.* NSW Agriculture, Goulburn.

Somerville D (1997), *Beekeeping in the Tumut-Tumbarumba State Forests.* NSW Agriculture, Goulburn.

Somerville D (1997), *Beekeeping in the Glen Innes State Forests.* NSW Agriculture, Goulburn.

Somerville D (1997), *Beekeeping in the Mildura Forestry Management Area.* NSW Agriculture, Goulburn.

Somerville D (1998), *Beekeeping in Dubbo State Forests.* NSW Agriculture, Goulburn.

Somerville D (1998), *Beekeeping in the Urbenville State Forests.* NSW Agriculture, Goulburn.

Somerville Doug (1999), *Floral Resource Database for the NSW Apiary Industry.* Final Report DAN 115A for the Rural Industries Research and Development Corporation. RIRDC Publication No. 99/174.

Somerville DC (2001), *Nutritional Value of Bee Collected Pollens.* Final report DAN 134A for the Rural Industries Research and Development Corporation. RIRIDC Publication No. 01/047.

Somerville D, Barnes I (1994), *Batemans Bay Forestry District Apiary Management Survey - September 1994.* NSW Agriculture, Goulburn

Somerville D, Bishop S (1997), *Beekeeping in the Kempsey State Forests.* NSW Agriculture, Goulburn.

Somerville D, Campbell S (1997), *Beekeeping in the Narrandera State Forests.* NSW Agriculture, Goulburn.

Somerville D, Colley C (1990), *Nowra State Forest apiary Management Survey.* NSW Agriculture, Goulburn.

Somerville D, Cooper M (1998), *Beekeeping in the Morisset State Forests.* NSW Agriculture, Goulburn.

Somerville D, Croft A (1998), *Beekeeping in the Bathurst/Oberon State Forests.* NSW Agriculture, Goulburn.

Somerville D, Dodds S (1995), *Narooma Forestry District Apiary Management Survey Results.* NSW Agriculture, Goulburn.

Somerville D, Hoffman T (1997), *Beekeeping in the Wauchope State Forests.* NSW Agriculture, Goulburn.

Somerville D, Murray J (1997), *Beekeeping in the Taree State Forests.* NSW Agriculture, Goulburn.

Somerville D, Murray J (1998), *Beekeeping in the Grafton State Forests.* NSW Agriculture, Goulburn.

Somerville D, Murray J (1998), *Beekeeping in the Urunga State Forests.* NSW Agriculture, Goulburn.

Somerville D, Raper E (1997), *Eden-Bombala Forestry District, Study of Beekeeper Usage and Importance.* NSW Agriculture, Goulburn.

Somerville D, Rienstra R (1997), *Beekeeping in the Inverell State Forests.* NSW Agriculture, Goulburn.

Somerville D, Robertson I (1998), *Beekeeping in the Casino State Forests.* NSW Agriculture, Goulburn.

Somerville D, Shannon R (1995), *Queanbeyan/Badja State Forest Management Area, Apiary Management Potential.* February 1995, NSW Agriculture, Goulburn.

Somerville D, Signor A (1998), *Beekeeping in the Gloucester/Walcha State Forests.* NSW Agriculture, Goulburn.

Somerville D, Thompson M (1995), *Central Murray Valley Forestry Area, Apiary Management Survey, May 1995.* NSW Agriculture, Goulburn.

Somerville D, Wells P (1996), *Forbes Forestry District, Apiary Management Survey Results.* NSW Agriculture, Goulburn.

Somerville D, Wilsom M (1998), *Beekeeping in the Dorrigo State Forests.* NSW Agriculture, Goulburn.

General Industry Publications

Somerville D (1997), *Bee Sites and Rural Lands Protection Boards in NSW - A Major Resource.* The Australasian Beekeeper **99** (4) 142-143.

Somerville D (1998), *Floral Resource Database.* NSW Apiarists' Association newsletter. September-October, 1998 9-12.

Somerville DC (1998), *State Forests - A Valuable Beekeeping Resource.* The Australasian Beekeeper **100** (3) 96-101.

Somerville D (1999), *NSW National Parks & Beekeeping.* The Australasian Beekeeper **100** (10) 404-407.

Somerville D (2000), *Pollen Quality - Almond (Prunnus dulcis).* The Australasian Beekeeper **101** (12) 417-518.

Somerville D (2000), *Pollen Quality - Alpine ash (Eucalyptus delegatensis).* The Australasian Beekeeper **101** (12) 518.

Somerville D (2000), *Pollen Quality - Apple box (Eucalyptus bridgesiana).* The Australasian Beekeeper **102** (1) 13-14.

Somerville D (2000), *Pollen Quality - Balansa clover (Trifolium balansae).* The Australasian Beekeeper **102** (1) 14-15.

Somerville D (2000), *Pollen Quality - Black/Spear thistle (Cirsium vulgare).* The Australasian Beekeeper **102** (4) 162.

Somerville D (2000), *Pollen Quality - Blakely's Red Gum (Eucalyptus blakelyi).* The Australasian Beekeeper **102** (4)162-163.

Somerville D (2000), *Pollen Quality - Blueberry (Vaccinium species).* The Australasian Beekeeper **102** (4) 163-164.

Somerville D (2000), *Pollen Quality - Brittle Gum (Eucalyptus mannifera).* The Australasian Beekeeper **102** (4) 164-165.

Somerville D (2000), *Pollen Quality - Buckwheat (Fagopynum esculentum).* The Australasian Beekeeper **102** (5) 197.

Somerville D (2000), *Pollen Quality - Canola (Brassica napus).* The Australasian Beekeeper **102** (5) 197-198.

Somerville D (2000), *Pollen Quality - Capeweed (Arctotheca calendula).* The Australasian Beekeeper **102** (5) 202-203.

Somerville D (2000), *Pollen Quality - Christmas Mallee (Eucalyptus socialis).* The Australasian Beekeeper **102** (5) 202-203.

Somerville D (2000), *Pollen Quality - Citrus (Citrus species).*
The Australasian Beekeeper **102** (6) 244.

Somerville D (2000), *Pollen Quality - Eggs & Bacon (Dillwynia species).*
The Australasian Beekeeper **102** (6) 245-246.

Somerville D (2000), *Pollen Quality - Faba bean (Vicia faba).*
The Australasian Beekeeper **102** (6) 246.

Somerville D (2000), *Pollen Quality - Fireweed (Senecio madagascariensis).*
The Australasian Beekeeper **102** (6) 247-248.

Somerville D (2001), *Pollen Quality - Banksias.*
The Australasian Beekeeper **102** (7) 282.

Somerville D (2001), *Pollen Quality - Brittle Gum (Eucalyptus mannifera).*
The Australasian Beekeeper **102** (7) 282.

Somerville D (2001), *Pollen Quality - Flatweed (Hypochoeris radicata).*
The Australasian Beekeeper **102** (7) 283-284.

Somerville D (2001), *Pollen Quality - Gorse (Ulex europaeus).*
The Australasian Beekeeper **102** (7) 284-285.

Somerville D (2001), *Pollen Quality - Grey gum (Eucalyptus punctata).*
The Australasian Beekeeper **102** (7) 286.

Somerville D (2001), *Pollen Quality - Grey Box (Eucalyptus microcarpa).*
The Australasian Beekeeper **102** (7) 285.

Somerville D (2001), *Pollen Quality - Lavender (Lavandula species).*
The Australasian Beekeeper **102** (8) 338-341.

Somerville D (2001), *Pollen Quality - Hedge Mustard (Sisymbrium officinale).* The Australasian Beekeeper **102** (8) 338.

Somerville D (2001), *Pollen Quality - Lupins (Lupinus angustifolius).* The Australasian Beekeeper **102** (8) 341.

Somerville D (2001), *Pollen Quality - Maize/Corn (Zea mays).* The Australasian Beekeeper **102** (8) 342-344.

Somerville D (2001), *Pollen Quality - Manna gum (Eucalyptus viminalis).* The Australasian Beekeeper **102** (9) 372-373.

Somerville D (2001), *Pollen Quality - Nodding thistle (Caduus nutans).* The Australasian Beekeeper **102** (9) 373.

Somerville D (2001), *Pollen Quality - Pollen Quality, Onion weed (Asphodelus fistulosus).* The Australasian Beekeeper **102** (10) 417.

Somerville D (2001), *Pollen Quality - Pear (Pyrus communis).* The Australasian Beekeeper **102** (10) 417.

Somerville D (2001), *Pollen Quality - Red Bloodwood (Corymbia gummifera).* The Australasian Beekeeper **102** (10) 417-418.

Somerville D (2001), *Pollen Quality - Red ironbark (Eucalyptus fibrosa).* The Australasian Beekeeper **102** (11) 458.

Somerville D (2001), *Pollen Quality - Red box (Eucalyptus polyanthemos).* The Australasian Beekeeper **102** (11) 458.

Somerville D (2001), *Pollen Quality - Red stringybark (Eucalyptus macrorhyncha).* The Australasian Beekeeper **102** (11) 458-459.

Somerville D (2001), *Pollen Quality - River red gum (Eucalyptus camaldulensis).* The Australasian Beekeeper **102** (12) 502.

Somerville D (2001), *Pollen Quality - Rough-barked apple (Angophora floribunda).* The Australasian Beekeeper **102** (12) 503.

Somerville D (2001), *Pollen Quality - Saffron thistle (Carthamus lanatus).* The Australasian Beekeeper **102** (12) 503.

Somerville D (2001), *Pollen Quality - Scribbly gum (Eucalyptus sclerophylla).* The Australasian Beekeeper **103** (1) 27.

Somerville D (2001), *Pollen Quality - Silky Hakea (Hakea sericea).* The Australasian Beekeeper **103** (1) 28.

Somerville D (2001), *Pollen Quality - Skeleton weed (Chondrilla juncea).* The Australasian Beekeeper **103** (1) 28-29.

Somerville D (2001), *Pollen Quality - Spotted gum (Corymbia maculata).* The Australasian Beekeeper **103** (2) 68.

Somerville D (2001), *Pollen Quality – Sunflower (Helianthus annus).* The Australasian Beekeeper **103** (2) 68-69.

Somerville D (2001), *Pollen Quality - Swamp mahogany (Eucalyptus robusta).* The Australasian Beekeeper **103** (2) 69.

Somerville D (2001), *In the apiary - Pollen Trapping and Storage.* The Australasian Beekeeper **103** (3) 107-112.

Somerville D (2001), *Pollen Quality - Sydney blue gum (Eucalyptus saligna).* The Australasian Beekeeper **103** (4) 165-167.

Somerville D (2001), *Pollen Quality - Turnip weed (Rapistrum rugosum).* The Australasian Beekeeper **103** (4) 167-170.

Somerville D (2001), *Pollen Quality - Vetch (Vicia species).* The Australasian Beekeeper **103** (4) 170.

Somerville D (2001), *Pollen Quality - Viper's bugloss (Echium vulgare).* The Australasian Beekeeper **103** (5) 199.

Somerville D (2001), *Pollen Quality - Wattle (Acacia species).* The Australasian Beekeeper **103** (5) 199-200.

Somerville D (2001), *Pollen Quality - White box (Eucalpytus albens).* The Australasian Beekeeper **103** (5) 200.

Somerville D (2001), *Pollen Quality - White clover (Trifolium repens).* The Australasian Beekeeper **103** (6) 233-234.

Somerville D (2001), *Pollen Quality - White mallee (Eucalyptus dumosa).* The Australasian Beekeeper **103** (6) 234-235.

Somerville D (2001), *Pollen Quality - White stringybark (Eucalyptus globoidea).* The Australasian Beekeeper **103** (6) 235-236.

Somerville D (2001), *Pollen Quality - Willows (Salix species).* The Australasian Beekeeper **103** (7) 298.

Somerville D (2001), *Pollen Quality - Woollybutt (Eucalyptus longifolia).* The Australasian Beekeeper **103** (7) 298-299.

Somerville D (2001), *Pollen Quality - Yellow burr (Centaurea solstitialis).* The Australasian Beekeeper **103** (7) 299.

APPENDIX 1

GLOSSARY OF BEEKEEPING TERMS

American foulbrood	AFB is an infectious bacteria which infects the brood of honey bees, caused by *Paenibacillus larvae* subsp. *larvae.*
Apiarist	one who keeps bees.
Apiary	a location/site with one or more bee hives.
Bee venom	the poisonous fluid produced by worker bees in their venom sacs and used in defence of their colony.
Beekeeper	one who keeps bees, apiarist.
Beeswax	a product of the wax glands in the worker bee—used for building combs and cells by bees. Used for many purposes once collected by humans.
Colony	a community of honey bees—queen, workers, drones and brood.
Commercial beekeeper	a person who keeps bees for the purposes of creating an income from the products or services provided from the hives—200 hives plus, usually 400 plus, by Australian standards.
Drone	male bee.
European foulbrood	EFB is an infectious bacteria which infects the brood of honey bees, caused by *Melissococcus pluton.*
Hive	the container within which the bees reside.
Hobbyist beekeeper	a person who keeps bees for the primary purpose of pleasure, interest and production of goods and or services for their own use. As a guide, 1 to 40 colonies may be considered a hobby.
Honey	defined as the sweet substance produced by honeybees from the nectar of blossoms or from secretions on living plants, which the bees collect, transform and store in honey combs.
Honey bees	*Apis mellifera L.* a four winged insect which gathers pollen and nectar as its primary ingredient to satisfy its nutritional requirements.
Nectar	the substance excreted by flowers, collected by bees to produce honey.
Nectar flow	a period of time when nectar is plentiful and bees produce and

	store surplus honey.
Nucleus	a small colony of bees, formed to make new hives or for queen rearing.
Package bees	a specified weight of bees contained in a wire-mesh cage, suitable for transporting great distances—usually contains a mated queen in its own cage.
Pollen	a substance collected by bees from flowers for the protein portion of their diet.
Pollination	the transfer of pollen from the male portion of the flower to the female portion of the flower.
Propolis	a glue-like substance collected by the field bees to close up cracks and holes in the bee-boxes and between the frames.
Queen breeder	one who raises queen bees for the purpose of requeening existing hives or starting new hives.
Registered beekeeper	a beekeeper who has paid the relevant fee to the State Government Department of Agriculture for the purposes of being a registered beekeeper under the relevant legislation.
Royal jelly	a substance excreted from the hypopharyngeal glands of nurse bees, used to feed the queen and young brood.
Semi commercial beekeeper	a person who keeps bees with the intention of making some or part of their income from the management of those hives. As a guide, 40 to 200 hives is considered a semi commercial operation.
Sideline beekeeper	same as semi commercial beekeeper.
Super	a box containing combs for the purpose of storing honey, placed on top of a brood box.
Worker	a female bee whose organs of reproduction have not developed who performs all the tasks in a hive except laying the eggs.

References:

Crane E (1976).

Somerville DC, White B and Rhodes J (2000).

APPENDIX 2

GLOSSARY OF PLANT BOTANICAL AND COMMON NAMES

Botanical name	Common name
Acacia anera	Mulga
Acacia baileyana	Cootamundra wattle
Acacia collectioides	Wait-a-while
Acacia doratoxylon	Currawong
Acacia elongata	Swamp wattle
Acacia longifolia	Sydney golden wattle
Acacia mearnsii	Black wattle
Acacia pendula	Myall
Acacia spp.	Wattle
Acacia tetragonophylla	Dead finish
Actinidia deliciosa	Kiwifruit
Aegiceras corniculatum	Black mangrove, River mangrove
Ageratina adenophora	Crofton weed
Ageratum conyzoides	Billygoat weed
Allium cepa	Garlic
Alphitonia excelsa	Blackheart, Mountain ash, Red ash, Soapbush
Ambrosia spp.	Ragweeds
Angophora bakeri	Narrow-leaved rough barked apple
Angophora costata	Rusty gum, Smooth-barked apple
Angophora floribunda	Rough-barked apple
Angophora hispida	Dwarf apple
Angophora melanoxylon	Coolabah apple
Angophora subvelutina	Broad leaved apple

Botanical name	Common name
Antirrhinum majus	Snapdragons
Aotus ericodes	Aotus
Arctotheca calendula	Capeweed
Asphodelus fistulosus	Onion weed
Atalaya hemiglauca	Whitewood
Avicennia marina	Grey mangrove, White mangrove
Backhousia myrtifolia	Grey myrtle
Banksia collina	Hill banksia
Banksia ericifolia	Heath-leaved banksia
Banksia integrifolia	Coast banksia
Banksia paludosa	Marsh banksia
Banksia serrata	Saw banksia
Banksia serratifolia	Wallum banksia
Banksia spp.	Banksia
Banksia spinulosa	Hairpin banksia
Boronia spp.	Boronia
Bossiaea obcordata	Spiny bossiea
Brassica campestris	Rape, Mustard
Brassica juncea	Indian mustard
Brassica kaber	Wild mustard
Brassica napus	Canola
Brassica nigra	Black mustard, Rapeseed
Brassica tournefortii	Wild radish, Wild turnip
Bursaria spinosa	Blackthorn
Caduus nutans	Nodding thistle
Callistemon salignus	White bottlebrush
Callistemon viminalis	Dropping bottlebrush, Red tea-tree
Calotis cuneifolia	Burr daisy

Botanical name	Common name
Calytrix tetragona	Hangdown, Fringe-myrtle
Carthamus lanatus	Saffron thistle
Cassia spp.	Butterbush
Cassinia arcuata	Chinese bush, Sifton bush
Casuarina cunninghamiana	River oak
Casuarina littoralis	Black she-oak
Casuarina spp.	Oak
Casuarina torulosa	Forest oak
Centaurea solstitialis	St Barnaby's thistle, Yellow burr
Chondrilla juncea	Skeleton weed
Chrysanthemoides monilifera	Bitou bush
Cirsium vulgare	Black thistle, Scotch thistle, Spear thistle
Citrus spp.	Citrus trees
Corymbia eximia	Yellow bloodwood
Corymbia gummifera	Red bloodwood
Corymbia henryi	Large-leaved spotted gum
Corymbia intermedia	Pink bloodwood
Corymbia maculata	Spotted gum
Corymbia trachyphloia	Pilliga bloodwood, White bloodwood
Corymbia variegata	Spotted gum
Crataegus spp.	Hawthorn
Cucmis melo	Rockmelon
Cucurbita maxima	Pumpkin
Dampiera stricta	Dampiera
Daviesia ulicifolia	Gorse bitter-pea
Dillwynia spp.	Eggs and bacon
Discaria toumatou	Matagouri

Botanical name	Common name
Dodonaea spp.	Hopbush
Echium plantagineum	Paterson's curse, Salvation Jane
Echium vulgare	Viper's bugloss
Eremophila duttonii	Harlequin fuchsia-bush
Eremophila gilesii	Turkey bush
Eremophila mitchellii	Budda
Eremophila spp.	Emu-bush
Eremophila sturtii	Sandalwood
Eremophila sturtii	Turpentine bush
Erisosteman spp.	Waxflowers
Ethretia membranifolia	Peach bush
Eucalyptus acmenoides	White mahogany
Eucalyptus agglomerata	Blue-leaved stringybark
Eucalyptus aggregata	Black gum
Eucalyptus albens	White box
Eucalyptus amplifolia	Cabbage gum
Eucalyptus andrewsii subsp. *andrewsii*	New England blackbutt
Eucalyptus andrewsii subsp. *campanulata*	New England blackbutt
Eucalyptus baueriana	Blue box
Eucalyptus behriana	Broad-leaved mallee box, Bull mallee
Eucalyptus beyeri	Beyer's ironbark, Corky ironbark
Eucalyptus blakelyi	Blakely's red gum, Red gum
Eucalyptus bosistoana	Coast grey box
Eucalyptus botryoides	Bangalay
Eucalyptus bridgesiana	Apple box
Eucalyptus caleyi	Caley's ironbark
Eucalyptus caliginosa	Broad-leaved stringybark

Botanical name	Common name
Eucalyptus camaldulensis	River red gum
Eucalyptus camphora	Red sally
Eucalyptus conica	Fuzzy box
Eucalyptus consideniana	Yertchuk
Eucalyptus crebra	Narrow-leaved ironbark
Eucalyptus dawsonii	Slaty box
Eucalyptus dealbata	Hill gum, Ridge gum, Sand gum, Smokey gum, Tumbledown gum
Eucalyptus deanei	Brown gum, Deane's gum
Eucalyptus deglupta	No common name
Eucalyptus delegatensis	Alpine ash
Eucalyptus diversicolor	Karri
Eucalyptus dumosa	White mallee
Eucalyptus dunnii	Dunn's white gum
Eucalyptus elata	River peppermint
Eucalyptus eugenioides	Thin-leaved stringybark
Eucalyptus fastigata	Brown barrel, Cut-tail
Eucalyptus fibrosa	Broad-leaved ironbark, Red ironbark
Eucalyptus fibrosia. subsp. *nubila*	Blue-leaved iron bark
Eucalyptus globoidea	White stringybark
Eucalyptus globulus	Blue gum, Eurabbie
Eucalyptus goniocalyx	Bundy
Eucalyptus gracilis	Mallee gum
Eucalyptus grandis	Flooded gum
Eucalyptus haemastoma	Scribbly gum

Botanical name	Common name
Eucalyptus incrassata	Giant mallee, Yellow mallee
Eucalyptus intertexta	Gum-barked coolibah, Western red box
Eucalyptus laevopinea	Clean limb, Silver-topped stringybark, White limb
Eucalyptus lansdowneana	Red-flowered mallee box
Eucalyptus largiflorens	Black box
Eucalyptus leucoxylon	Yellow gum
Eucalyptus longifolia	Woollybutt
Eucalyptus macrorhyncha	Red stringybark
Eucalyptus mannifera subsp. *maculosa*	Brittle gum
Eucalyptus marginata	Jarrah
Eucalyptus melanophloia	Silver-leaved ironbark
Eucalyptus melliodora	Yellow box
Eucalyptus microcarpa	Brown box, Western grey box
Eucalyptus microcroys	Tallowwood
Eucalyptus microtheca	Coolibah
Eucalyptus moluccana	Grey box, Gum-topped box
Eucalyptus muelleriana	Yellow stringybark
Eucalyptus nigra	Grey stringybark, White stringybark
Eucalyptus nitens	Shining gum
Eucalyptus nortonii	Blue apple, Long leaved box
Eucalyptus obliqua	Broad-leaved messmate
Eucalyptus oblonga	Narrow-leaved stringybark
Eucalyptus ochropholia	Napunyah
Eucalyptus oleosa	Red mallee

Botanical name	Common name
Eucalyptus oreades	Blue mountain ash
Eucalyptus paniculata	Grey ironbark
Eucalyptus parramattenis	Parramatta gum
Eucalyptus pauciflora	Snow gum
Eucalyptus pilligaenis	Narrow-leaved grey box, Pilliga box
Eucalyptus pilularis	Blackbutt
Eucalyptus piperita	Sydney peppermint
Eucalyptus planchoniana	Needlebark stringybark
Eucalyptus polyanthemos	Red box
Eucalyptus polybractea	Blue mallee
Eucalyptus populnea	Bimble box
Eucalyptus propinqua	Small-fruited grey gum, Grey gum
Eucalyptus punctata	Large-fruited grey gum, Grey gum
Eucalyptus racemosa	Scribbly gum
Eucalyptus radiata	Narrow-leaved peppermint
Eucalyptus radiata subsp. *robertsonii*	Robertson's peppermint
Eucalyptus regnans	Mountain ash
Eucalyptus resinifera	Red mahogany, Red stringybark
Eucalyptus robusta	Swamp mahogany
Eucalyptus rossii	Scribbly gum
Eucalyptus rubida	Candlebark gum
Eucalyptus saligna	Sydney blue gum
Eucalyptus sclerophylla	Scribbly gum
Eucalyptus seeana	Mountain red gum, Narrow-leaved red gum
Eucalyptus siderophloia	Grey ironbark
Eucalyptus sideroxylon	Mugga
Eucalyptus sieberi	Silvertop ash

Botanical name	Common name
Eucalyptus signatta	Scribbly gum
Eucalyptus socialis	Christmas mallee
Eucalyptus spp.	Stringybarks
Eucalyptus stellulata	Black sally
Eucalyptus tereticornis	Blue gum, Forest red gum, Red gum
Eucalyptus umbra	Broad-leaved white mahogany
Eucalyptus viminalis	Ribbon gum
Eucalyptus viridis	Green mallee
Eucryphia moorei	Leatherwood, Pinkwood
Eupatorium riparium	Mist flower
Fagopyrum esculentum	Buckwheat
Geijera parviflora	Wilga
Glycine max	Soyabean
Gompholobium latifolium	Giant wedge-pea
Goodenia bellidifolia	Goodenia
Gossypium hirsutum	Cotton
Guioa semiglauca	Crow's ash
Helianthus annuus	Sunflower
Heliotropium amplexicaule	Caterpillar weed, Purple top
Hieracium pilosela	Hawkweed
Hypochoeris radicata	Flatweed
Jacksonia scoparia	Dogwood
Leptospermum flavescens	Common tea-tree, Jelly bush, Wild may
Leptospermum spp.	Tea tree
Ligustrum spp.	Privet
Lophostemon confertus	Brush box

Botanical name	Common name
Lophostemon suavelolens	Swamp box, Swamp turpentine, Water gum
Macadamia spp.	Macadamia
Malus domestica	Apple
Marrubium vulgare	Horehound
Medicago polymorpha	Trefoil
Medicago sativa	Lucerne
Melaleuca quinquenervia	Belbowrie, Broad-leaved tea-tree
Melaleuca spp.	Tea tree
Melaleuca styphelioides	Prickly-leaved tea-tree
Melilotus spp.	Sweet clover
Micromyrtus ciliata	Heath-myrtle
Muehlenbeckia cunninghamii	Lignum
Myoporum deserti	Ellangowan
Myoporum montanum	Boobialla Native daphne
Myriocephalus stuartii	Poached egg daisy
Olearia spp.	Daisy-bushes
Onopordum acanthium	Scotch thistle
Oxylobium lilicifolium	Native holly
Persea americana	Avocado
Persoonia spp.	Geebung
Petunia hybrida	Petunias
Phebalium spp.	Phebalium
Pittosporum undulatum	Mock orange
Pluchea spp.	Daisy-bushes
Polygonum aviculare	Hogweed, Wireweed
Prunus dulcis	Almond

Botanical name	Common name
Prunus spp.	Cherry, Nectarine, Peach, Plum, Prune
Psidium guajava	Guava
Pyrus communis	Pear
Raphanus sativus	Radish
Rapistrum rugosum	Turnip weed
Rubus fruticosus	Blackberry
Saccharum officinarum	Sugar cane
Salix discolour	Pussy willow
Salix fragilis	Crack willow
Salix spp.	Willows
Senecio madagascariensis	Fireweed
Silybum marianum	Variegated thistle
Sisymbrium officinale	Hedge mustard
Syncarpia glomulifera	Turpentine
Taraxacum officinale	Dandelion
Taraxacum vulgare	Dandelion
Thryptomene micrantha	Heather bush
Tribulus terrestris	Caltrop, Cathead, Yellow vine
Trifolium alexandrium	Egyptian clover
Trifolium balansae	Balansa clover
Trifolium pratense	Red clover
Trifolium repens	White clover
Ulex europaeus	Gorse
Vicia faba	Faba beans
Vicia sativa	Vetch
Xanthorrhoea spp.	Grasstree

APPENDIX 3

SURVEY FORM AND LETTERS (Chapter 4)

- Letter to beekeepers (23 April, 1997)
- Covering note (23 April, 1997)
- Survey forms
- Second letter to beekeepers (1 August, 1997)
- Third letter to beekeepers (25 November, 1998)

NSW Agriculture

PO Box 389
NSW Government Offices
159 Auburn Street
GOULBURN NSW 2580

Telephone: (048) 230 616
Facsimile: (048) 223 261

SURVEY
NSW Apicultural Floral Database

Dear Beekeeper

The Honey Bee Research and Development Committee have provided funds to every state to conduct a census/survey of the commercial beekeepers to compile a comprehensive list of the most valuable or core species that the industry requires for its continued viability.

The task of collecting the information and then compiling it will be immense, but the final document will depend on the quality of information supplied by **"you"**. All beekeepers with 200 hives plus in NSW have been sent a survey form. Your participation and cooperation in this task is appreciated and is most important in putting together a comprehensive document on our State's flora, as it relates to beekeeping.

Read the following notes and fill out the census forms. If there are any questions, please do not hesitate in phoning me at work or home. Contact numbers for Doug Somerville:

Work: (048) 230619; Fax: (048) 223261; Home: (048) 215303; Mobile: (014) 818925
Email address: somervd@agric.nsw.gov.au

"The aims and objectives of this project are to clearly define the floral resource base on which the industry is dependent on. The distribution of the various species as they relate to beekeeping, the frequency with which these resources are used, the land tenure on which they currently exist, and the relative values for honey and pollen levels of importance as they relate to honey bee nutritional requirements and honey production (these two points are interwoven and any study needs to highlight this).

Some data on the reliance on interstate floral resources, employment and derivatives of income base for beekeeping, will assist in placing the floral resource data into some focus and perspective."

Please fill out the attached survey forms and return them ***by 30th June*** in the envelope provided. In anticipation, thank you for your involvement.

Regards

DOUG SOMERVILLE
APIARY OFFICER
GOULBURN
23 APRIL, 1997

CENSUS OF THE NATURAL RESOURCE DATABASE FOR THE NSW APIARY INDUSTRY

Conducted by: Doug Somerville

NOTE: All personal information collected will be kept **strictly confidential**.

Any information you supply will be grouped together with other NSW beekeepers to obtain a clear picture of the State of the NSW beekeeping industry and the level of importance of the various floral species.

Every commercial beekeeper with over 200 hives will be asked to participate in the census and it is important that all beekeepers make the effort to take the time to record the relevant information on the forms provided.

Please provide information on the PRIMARY or most important resources to your beekeeping operation.

There is a general form asking for the number of hives, total honey production, etc. Please complete this to the best of your knowledge for your operation.

It is vital to the success of this project that you provide as much information as possible in the floral database census forms.

NSW BEEKEEPING CENSUS

Beekeepers Name or Registration Number: ______________________________

	Average number of working hives over the last five (5) years.
	Average number of nucleus colonies over the last five (5) years.
	Average annual honey production over the last five (5) years (kgs or tonnes - please state which).
	What percentage (%) of your annual five (5) year average honey crop is obtained interstate, e.g., Victoria or Queensland.
	How many persons does your beekeeping business employ (including yourself), e.g., 1¼ means yourself and another person employed for three (3) months of the year.

How many sites in total have you occupied on the following land tenures in the last five (5) years?

State Forests	**National Parks & Wildlife**	**Crown Land**	**Rural Lands** **Protection Board**	**Private Property**

DISTRIBUTION OF GROSS INCOME OVER THE LAST FIVE (5) YEARS

	%	**EXAMPLE**
Honey production		75%
Comb honey		
Bees wax		5%
Pollination		10%
Queen bees		-
Package bees		10%
Other - please state		

NSW FLORAL DATABASE - CENSUS FORM

Beekeepers Name or Registration No: ______________________

Floral species of importance to your beekeeping in NSW. (Refer to notes.)

Office Use	Species (Common or Scientific name)	Level of importance Low → High 1,2,3,4,5	Expected Yields (Tins or kg per hive?)	Time of year flowering occurs (Months)	How many years between flows	How many sites on this species					Nearest town to bulk of sites, direction (e.g., SE, NW) & km's
		Pollen	Honey			SF	NPWS	CL	RLPB	Private	

1st August, 1997

NSW Agriculture

STRICTLY CONFIDENTIAL

NSW Apicultural Floral Database

PO Box 389
NSW Government Offices
159 Auburn Street
GOULBURN NSW 2580

Telephone: (048) 230 616
Facsimile: (048) 223 261

Dear Beekeeper

Sit down, have a cup of tea and take a few moments to consider the following:

1. The Honey Bee Research & Development Council has funded NSW Agriculture to conduct a State survey of floral resources – your money, via research levies, is paying for the exercise.

2. This is a second mailing of the survey form sent in April and due by 30th June. The first round attracted a 40% response.

3. Concern or confidentially has been expressed by a number of beekeepers. You or your specific site information **<u>will not</u>** be identifiable in any report generated by me. The information on any form will be kept in the strictest confidence.

4. The success of this project depends on your participation.

5. This survey is not just about Forestry and National Park sites. Beekeeping resources are being reduced via a multitude of pressures including urban sprawl, eucalypt dieback, firewood cutters, clearing of native timber for pine plantation, salt inundation killing or affecting flowering patterns, continued clearing in some areas of the State, biological control of certain weeds and general suppression of certain weed species. Basically, resource issues relate to all beekeepers in NSW in some form or manner, thus your information and input into this survey is very important.

6. Please take a little time and provide as much information as you see appropriate on the "primary" or "most important" floral resources to your beekeeping operation.

7. Please return (in Reply Paid envelope provided) by **<u>31st August</u>**. If you have any problems or questions, please contact me:
Work: (048) 230619; Fax: (048) 223261; Home: (048) 215303; Mobile: (014) 818925. Email address: somervd@agric.nsw.gov.au.

Regards

Doug Somerville
Apiary Officer
GOULBURN

25th November, 1998

NSW Agriculture

PO Box 389
NSW Government Offices
159 Auburn Street
GOULBURN NSW 2580

Telephone: (048) 230 616
Facsimile: (048) 223 261

Dear Beekeeper

Last Chance!

Floral resources (honey and pollen plants) are the backbone of your beekeeping enterprise — without them, your bees starve and you go broke. Your money, through the Honey Bee Research & Development Council, is being used to record all the important honey and pollen plants in NSW.

Last year you were sent a survey form but, as yet, I have not received a reply. I have received replies from 70% of the beekeeping industry — you are the other 30%. It is important that we, as an industry, know exactly what is important to you as far as honey and pollen plants go. I now send you a form in the hope that we will achieve a 100% response for the benefit of the beekeeping industry. There is no need to spend days on this form — **5 to 10 minutes is sufficient**. Your best guess is all that is required. List only your top 6 or 12 honey and/or pollen plants, trees or weeds — it doesn't matter. Your response to this survey will fill gaps in the big picture.

The beekeeping industry associations working on your behalf will, no doubt, use the information from this report for your benefit. Your individual information will be kept private and confidential by me - all information is grouped in the final report.

Please take a few minutes to fill out the attached forms and return them, in the REPLY PAID envelope (***no stamp required***) by the 18th December – sooner rather than later. To all those beekeepers who do respond to this survey, they will be sent a copy of the final report mid next year.

All the best for Christmas and I hope your hives are full of honey.

Regards

Doug Somerville
Apiary Officer
Goulburn

APPENDIX 4

LIST OF MELLIFEROUS SPECIES AS PROVIDED BY BEEKEEPERS IN THE SURVEY BY NUMBER OF RESPONSES (CHAPTER 4).

Botanical name	Common name	Responses
Echium plantagineum	Paterson's curse, Salvation Jane	191
Eucalyptus melliodora	Yellow box	160
Eucalyptus paniculata, Eucalyptus siderophloia	Grey ironbark	160
Corymbia maculata, Corymbia variegata	Spotted gum	139
Brassica napus	Canola	113
Eucalyptus macrorhyncha	Red stringybark	104
Eucalyptus camaldulensis	River red gum	93
Eucalyptus sideroxylon	Mugga	91
Eucalyptus albens	White box	86
Trifolium repens	White clover	83
Lophostemon confertus	Brush box	78
Corymbia gummifera	Red bloodwood	70
Eucalyptus pilularis	Blackbutt	64
Eucalyptus acmenoides	White mahogany	60
Eucalyptus fibrosa	Broad-leaved ironbark, Red ironbark	59
Eucalyptus dealbata	Hill gum, Smokey gum, Tumbledown gum, Ridge gum, Sand gum	59
Eucalyptus largiflorens	Black box	52
Rapistrum rugosum	Turnip weed	50
Corymbia trachyphloia	White bloodwood, Pilliga bloodwood	50
Eucalyptus bridgesiana	Apple box	49
Melaleuca quinquenervia	Broad leaved tea-tree, Belbowrie	48
Eucalyptus microtheca	Coolibah	45

Botanical name	Common name	Responses
Eucalyptus crebra	Narrow-leaved ironbark	44
Eucalyptus microcarpa	Western grey box, Brown box	43
Eucalyptus blakelyi	Blakely's red gum, Red gum	42
Centaurea solstitialis	St Barnaby's thistle, Yellow burr	38
Eucalyptus tereticornis	Forest red gum, Blue gum, Red gum	37
Eucalyptus melanophloia	Silver-leaved ironbark	36
Eucalyptus caliginosa	Broad-leaved stringybark	35
Eucalyptus muelleriana	Yellow stringybark	35
Eucalyptus viridis	Green mallee	34
Medicago sativa	Lucerne	33
Eucalyptus viminalis	Ribbon gum	33
Banksia ericifolia	Heath-leaved banksia	30
Onopordum acanthium	Scotch thistle	30
Angophora floribunda	Rough-barked apple	29
Eucalyptus globoidea	White stringybark	29
Arctotheca calendula	Capeweed	28
Eucalyptus moluccana	Grey box, Gum topped box	28
Eucalyptus saligna	Sydney blue gum	28
Eucalyptus andrewsii subsp. *andrewsii*	New England blackbutt	27
Eucalyptus socialis	Christmas mallee	24
Eucalyptus laevopinea	Silver-topped stringybark, Clean limb, White limb	24
Echium vulgare	Viper's bugloss	24
Dillwynia spp.	Eggs and bacon	23
Eucalyptus propinqua, *Eucalyptus punctata*	Grey gum	23
Eucalyptus spp.	Stringybarks	23
Eucalyptus pauciflora	Snow gum	22
Eucalyptus caleyi	Caley's ironbark	20
Hypochoeris radicata	Flatweed	20
Eucalyptus resinifera	Red mahogany, Red stringybark	20

Botanical name	Common name	Responses
Citrus spp.	Citrus trees	19
Eucalyptus ochropholia	Napunyah	19
Eucalyptus populnea	Bimble box	18
Eucalyptus pilligaenis	Pilliga box, Narrow-leaved grey box	17
Eucalyptus longifolia	Woollybutt	17
Eucalyptus goniocalyx	Bundy	16
Micromyrtus ciliata, *Calytrix tetragona*	Fringed heath-myrtle, Hangdown, Goo-bush	16
Eucalyptus piperita	Sydney peppermint	16
Eucalyptus oleosa	Red mallee	15
Eucalyptus grandis	Flooded gum	14
Eucalyptus punctata	Large-fruited grey gum	14
Senecio madagascariensis	Fireweed	13
Eucalyptus stellulata	Black Sally	11
Eucalyptus fastigata	Cut-tail, Brown barrell	11
Macadamia spp.	Macadamia	11
Eucalyptus robusta	Swamp mahogany	11
Eucalyptus microcroys	Tallowwood	11
Syncarpia glomulifera	Turpentine	11
Eucalyptus rubida	Candlebark gum	10
Eucalyptus signatta	Scribbly gum	10
Angophora costata	Smooth-barked apple, Rusty gum	10
Lophostemon suavelolens	Swamp turpentine, Water gum, Swamp box	10
Melaleuca spp.	Tea tree	10
Acacia spp.	Wattle	10
Eucalyptus dumosa	White mallee	10
Eucalyptus beyeri	Beyer's ironbark, Corky ironbark	9
Eucalyptus mannifera subsp. *maculosa*	Brittle gum	9
Tribulus terrestris	Caltrop, Cathead, Yellow vine	9
Guioa semiglauca	Crow's ash	9

Botanical name	Common name	Responses
Taraxacum officinale	Dandelion	8
Eucalyptus siderophloia	Grey ironbark	8
Eucalyptus planchoniana	Needlebark stringybark	8
Eucalyptus propinqua	Small-fruited grey gum	8
Cirsium vulgare	Spear thistle, Black thistle, Scotch thistle	8
Eucalyptus delegatensis	Alpine ash	7
Eucalyptus agglomerata	Blue-leaved stringybark	7
Eucalyptus intertexta	Gum-barked coolibah, Western red box	7
Corymbia henryi	Large-leaved spotted gum	7
Eucalyptus polyanthemos	Red box	7
Alphitonia excelsa	Soapbush, Mountain ash, Blackheart, Red ash	7
Eucalyptus botryoides	Bangalay	6
Banksia spp.	Banksia	6
Eucalyptus rossii	Scribbly gum	6
Eucalyptus sclerophylla	Scribbly gum	6
Corymbia eximia	Yellow bloodwood	6
Eucalyptus globulus	Blue gum, Eurabbie	5
Heliotropium amplexicaule	Caterpillar weed, Purple top	5
Leptospermum flavescens	Common tea-tree, Wild may, Jelly bush	5
Casuarina torulosa	Forest oak	5
Eucalyptus conica	Fuzzy box	5
Muehlenbeckia cunninghamii	Lignum	5
Eucalyptus gracilis	Mallee gum	5
Eucalyptus sieberi	Silvertop ash	5
Chondrilla juncea	Skeleton weed	5
Eremophila sturtii	Turpentine bush, Sandalwood	5
Brassica tournefortii	Wild turnip, Wild radish	5
Acacia mearnsii	Black wattle	4

Botanical name	Common name	Responses
Bursaria spinosa	Blackthorn	4
Angophora subvelutina	Broad-leaved apple	4
Eucalyptus obliqua	Broad-leaved messmate	4
Eucalyptus umbra	Broad-leaved white mahogany	4
Eremophila mitchellii	Budda	4
Eucalyptus amplifolia	Cabbage gum	4
Banksia integrifolia	Coast banksia	4
Eucalyptus bosistoana	Coast grey box	4
Myoporum deserti	Ellangowan	4
Eucalyptus incrassata	Giant mallee, Yellow mallee	4
Avicennia marina	Grey mangrove, White mangrove	4
Dodonaea spp.	Hopbush	4
Casuarina spp.	Oak	4
Asphodelus fistulosus	Onion weed	4
Carthamus lanatus	Saffron thistle	4
Salix spp.	Willows	4
Trifolium balansae	Balansa clover	3
Eucalyptus aggregata	Black gum	3
Eucalyptus oreades	Blue mountain ash	3
Olearia spp., *Pluchea* spp.	Daisy-bushes	3
Jacksonia scoparia	Dogwood	3
Vicia faba	Faba beans	3
Banksia spinulosa	Hairpin banksia	3
Thryptomene micrantha	Heather bush	3
Banksia paludosa	Marsh banksia	3
Acacia anera	Mulga	3
Eucalyptus radiata	Narrow-leaved peppermint	3
Eucalyptus andrewsii subsp. *campanulata*	New England blackbutt	3
Eucalyptus parramattenis	Parramatta gum	3

Botanical name	Common name	Responses
Prunus spp.	Peach, Nectarine, Plum, Prune, Cherry	3
Eucryphia moorei	Pinkwood, Leatherwood	3
Melaleuca styphelioides	Prickly-leaved tea-tree	3
Banksia serrata	Saw banksia	3
Eucalyptus dawsonii	Slaty box	3
Helianthus annuus	Sunflower	3
Acacia longifolia	Sydney golden wattle	3
Eucalyptus eugenioides	Thin-leaved stringybark	3
Silybum marianum	Variegated thistle	3
Acacia collectioides	Wait-a-while	3
Polygonum aviculare	Wireweed, Hogweed	3
Chrysanthemoides monilifera	Bitou bush	2
Eucalyptus polybractea	Blue mallee	2
Eucalyptus fibrosia. subsp *nubila*	Blue-leaved iron bark	2
Myoporum montanum	Boobialla, Native daphne	2
Gossypium hirsutum	Cotton	2
Acacia doratoxylon	Currawong	2
Callistemon viminalis	Dropping bottlebrush, Red tea-tree	2
Sisymbrium officinale	Hedge mustard	2
Marrubium vulgare	Horehound	2
Pittosporum undulatum	Mock orange	2
Angophora bakeri	Narrow-leaved rough barked apple	2
Oxylobium lilicifolium	Native holly	2
Carduus nutans	Nodding thistle	2
Corymbia intermedia	Pink bloodwood	2
Eucalyptus camphora	Red sally	2
Aegiceras corniculatum	River mangrove, Black mangrove	2
Casuarina cunninghamiana	River oak	2
Cucmis melo	Rockmelon	2

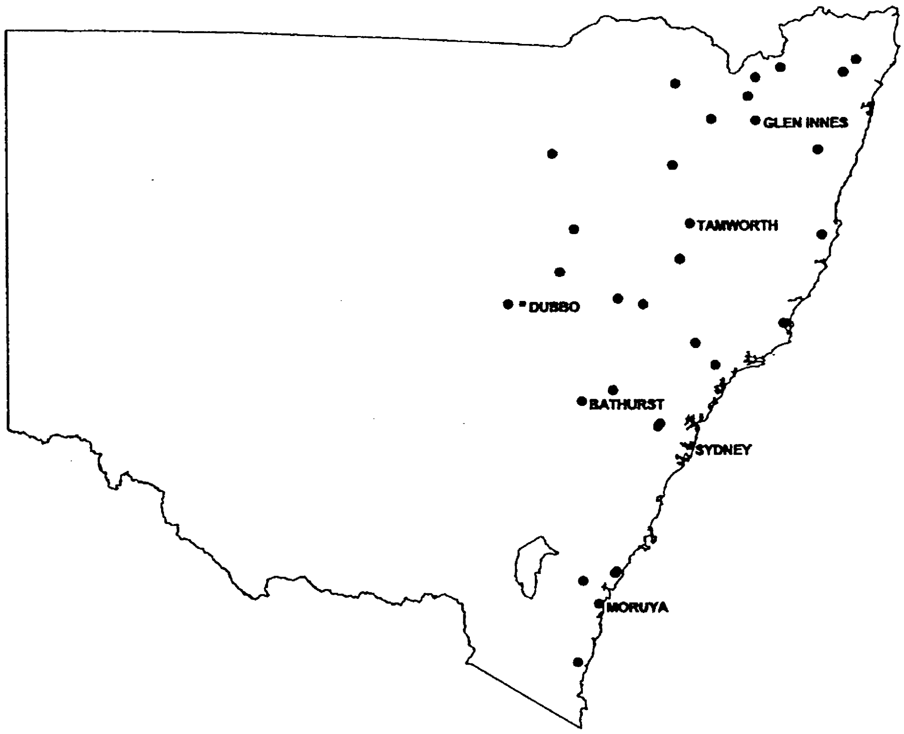
Botanical name	Common name	Responses
Cassinia arcuata	Sifton bush, Chinese bush	2
Medicago polymorpha	Trefoil	2
Banksia serratifolia	Wallum banksia	2
Eucalyptus consideniana	Yertchuk	2
Malus domestica	Apple	1
Persea americana	Avocado	1
Ageratum conyzoides	Billygoat weed	1
Casuarina littoralis	Black she-oak	1
Rubus fruticosus	Blackberry	1
Eucalyptus nortonii	Blue apple, Long-leaved box	1
Eucalyptus baueriana	Blue box	1
Boronia spp.	Boronia	1
Eucalyptus deanei	Brown gum, Deane's gum	1
Fagopyrum esculentum	Buckwheat	1
Eucalyptus behriana	Bull mallee, Broad-leaved mallee box	1
Calotis cuneifolia	Burr daisy	1
Cassia spp.	Butterbush	1
Angophora melanoxylon	Coolabah apple	1
Acacia baileyana	Cootamundra wattle	1
Ageratina adenophora	Crofton weed	1
Acacia tetragonophylla	Dead finish	1
Angophora hispida	Dwarf apple	1
Eremophila spp.	Emu-bush	1
Persoonia spp.	Geebung	1
Gompholobium latifolium	Giant wedge-pea	1
Ulex europaeus	Gorse	1
Daviesia ulicifolia	Gorse bitter-pea	1
Xanthorrhoea spp.	Grasstree	1
Backhousia myrtifolia	Grey myrtle	1
Eucalyptus nigra	Grey stringybark, White stringybark	1
Eremophila duttonii	Harlequin fuchsia-bush	1

Botanical name	Common name	Responses
Crataegus spp.	Hawthorn	1
Banksia collina	Hill banksia	1
Eupatorium riparium	Mist flower	1
Acacia pendula	Myall	1
Eucalyptus seeana	Narrow-leaved red gum, Mountain red gum	1
Eucalyptus oblonga	Narrow-leaved stringybark	1
Ethretia membranifolia	Peach bush	1
Pyrus communis	Pear	1
Phebalium spp.	Phebalium	1
Myriocephalus stuartii	Poached egg daisy	1
Ligustrum spp.	Privet	1
Cucurbita maxima	Pumpkin	1
Ambrosia spp.	Ragweeds	1
Eucalyptus elata	River peppermint	1
Eucalyptus radiata subsp. *robertsonii*	Robertson's peppermint	1
Eucalyptus haemastoma	Scribbly gum	1
Eucalyptus racemosa	Scribbly gum	1
Glycine max	Soyabean	1
Bossiaea obcordata	Spiny bossiea	1
Saccharum officinarum	Sugar cane	1
Acacia elongata	Swamp wattle	1
Melilotus spp.	Sweet clover	1
Leptospermum spp.	Tea tree	1
Eremophila gilesii	Turkey bush	1
Vicia sativa	Vetch	1
Erisosteman spp.	Waxflowers	1
Callistemon salignus	White bottlebrush	1
Geijera parviflora	Wilga	1
Atalaya hemiglauca	Whitewood	1

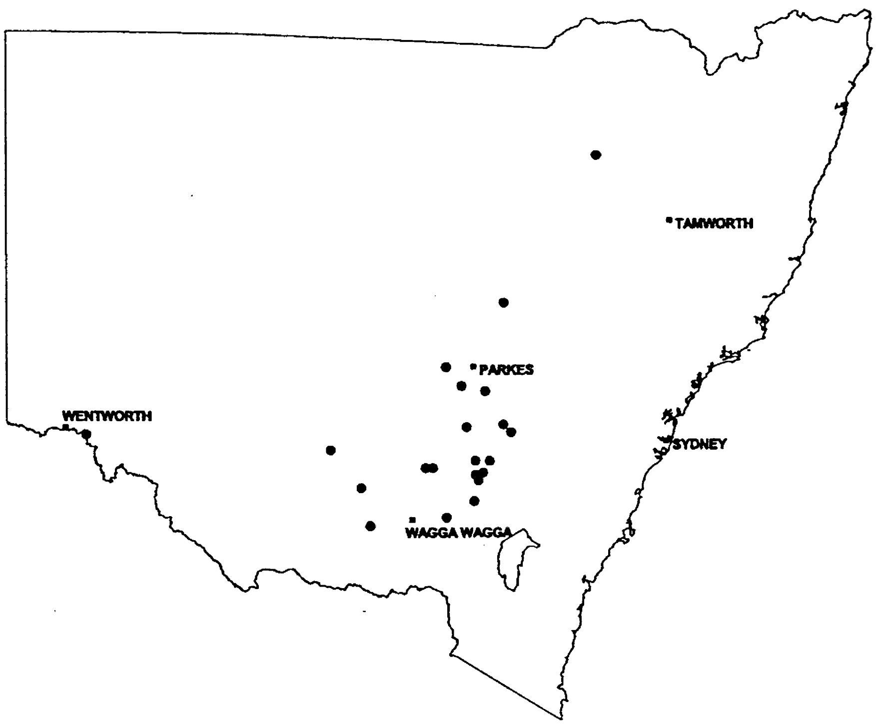
APPENDIX 5

DISTRIBUTION MAPS OF THE TOP 51 SPECIES MENTIONED BY BEEKEEPERS IN THE STATE SURVEY
(species mentioned 20 or more times in individual returns, refer Chapter 4)

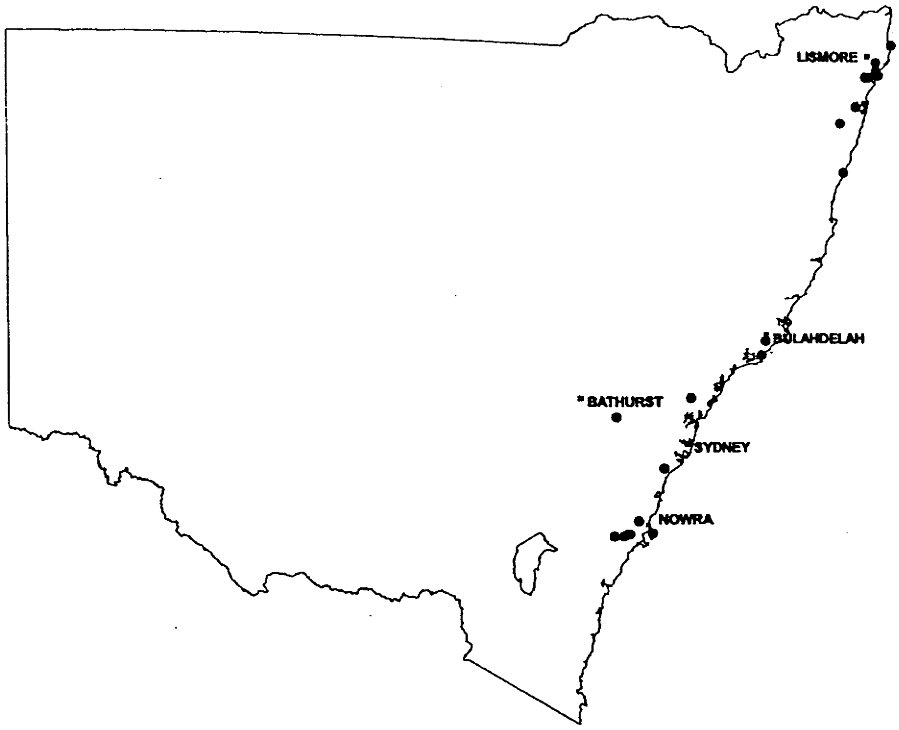
Angophora floribunda (Rough-barked apple)



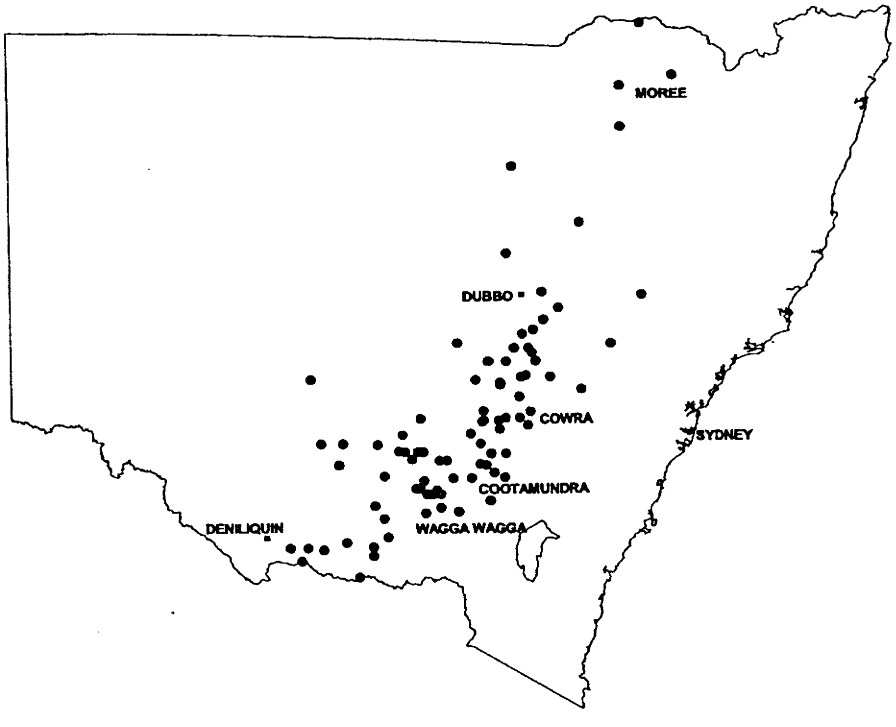
Arctotheca calendula (Capeweed)



Banksia ericifolia (Heath-leaved banksia)

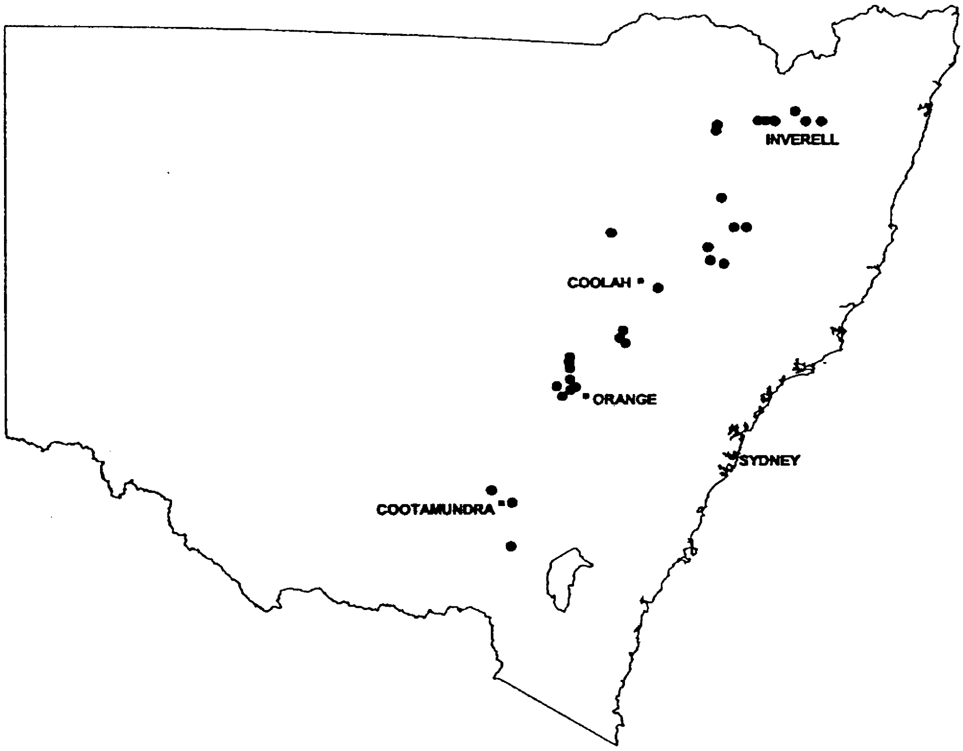


Brassica napus (Canola)

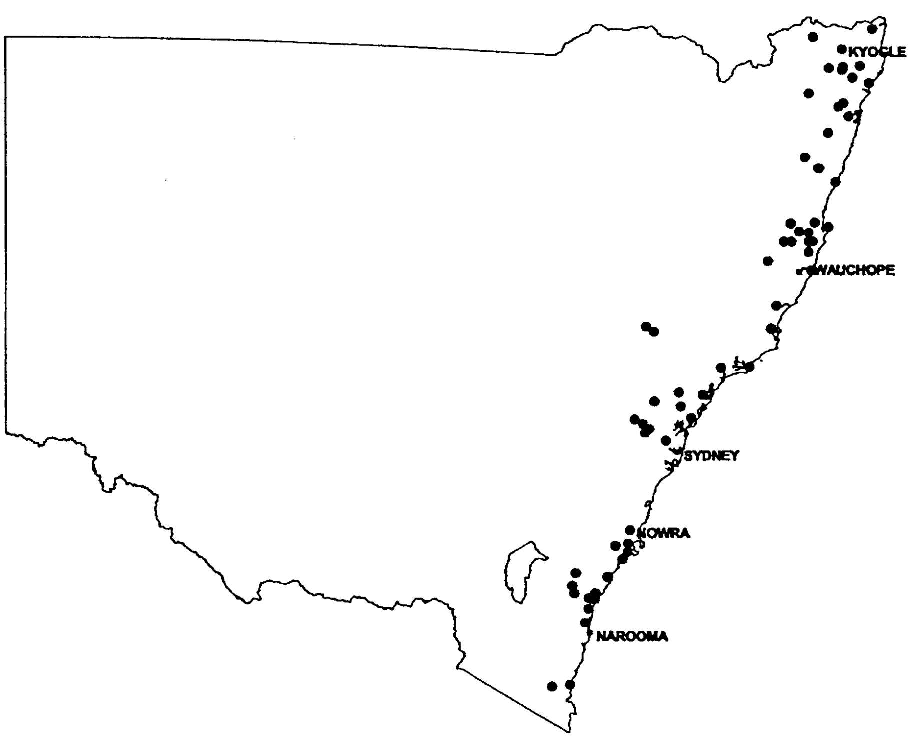


Centaurea solstitialia (St Barnaby's thistle)

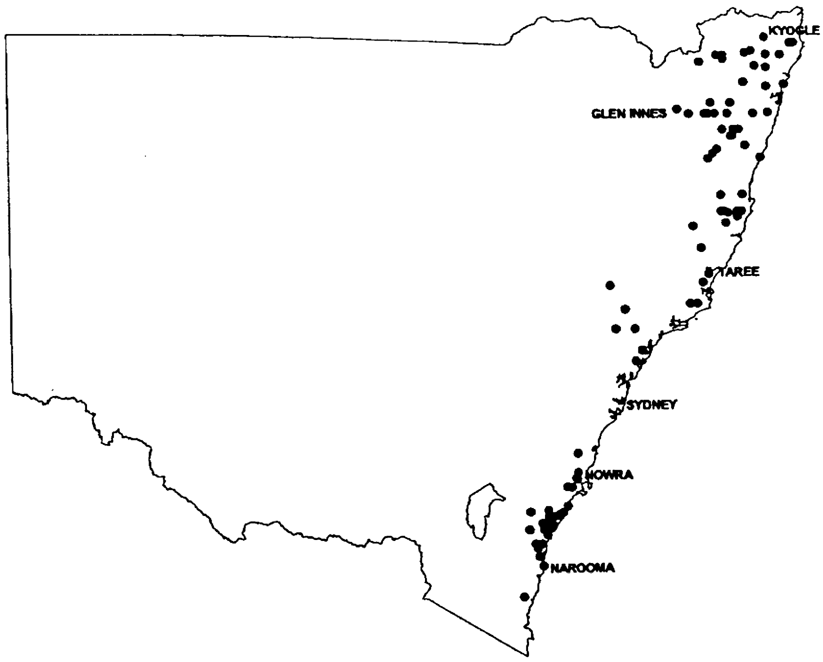
(also referred to as Yellow burr)



Corymbia gummifera (Red bloodwood)

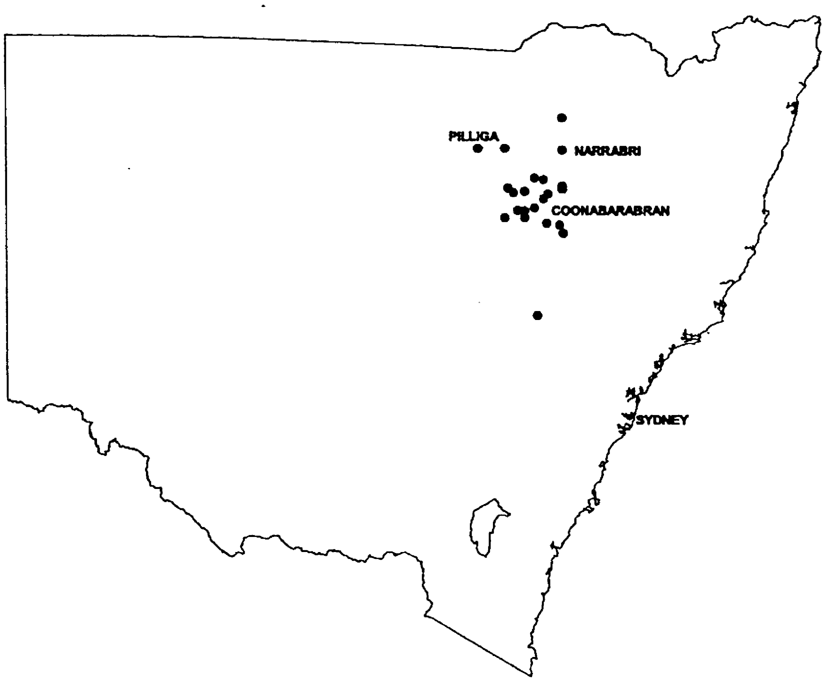


***Corymbia maculata/C. variegata* (Spotted gum)**

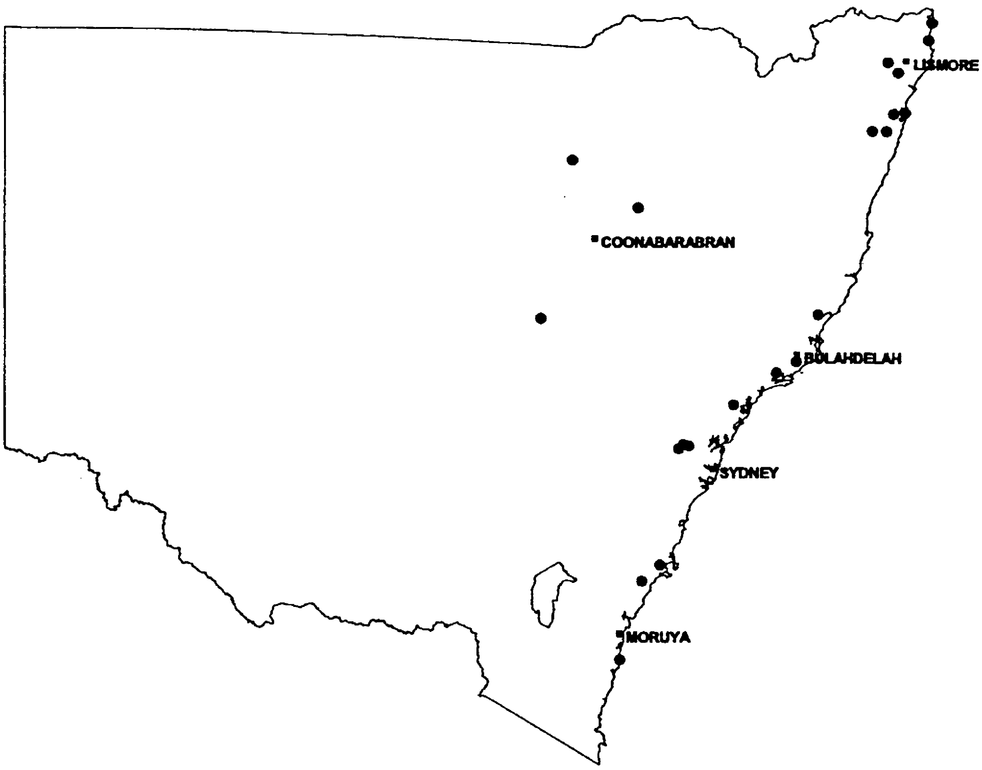


Previously *C. maculata* occurred the length of NSW. The species has been split, with *C. maculata* extending from southern NSW to Coffs Harbour, and *C. variegata* extending from south of Coffs Harbour into Queensland.

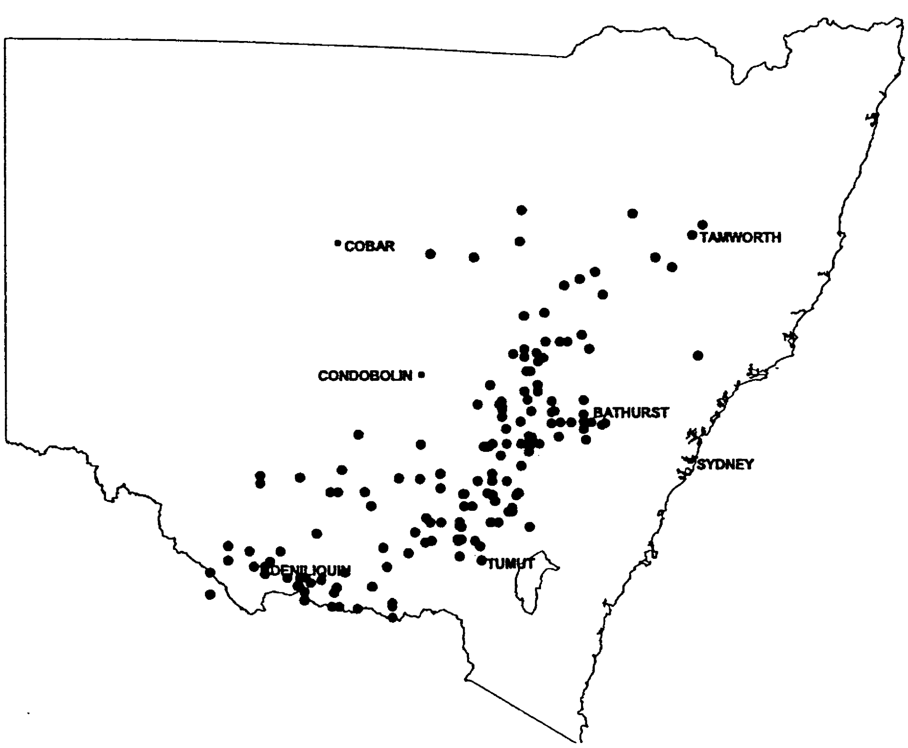
***Corymbia trachyphloia* (White bloodwood)**
(also referred to as Pilliga bloodwood)



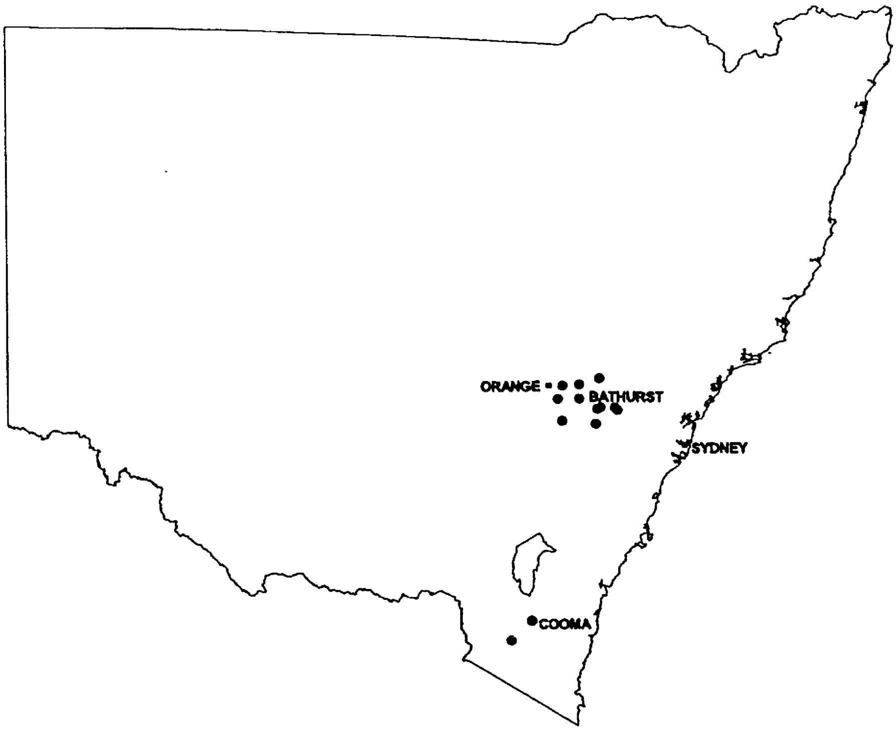
Dillwynia spp. (Eggs and bacon)



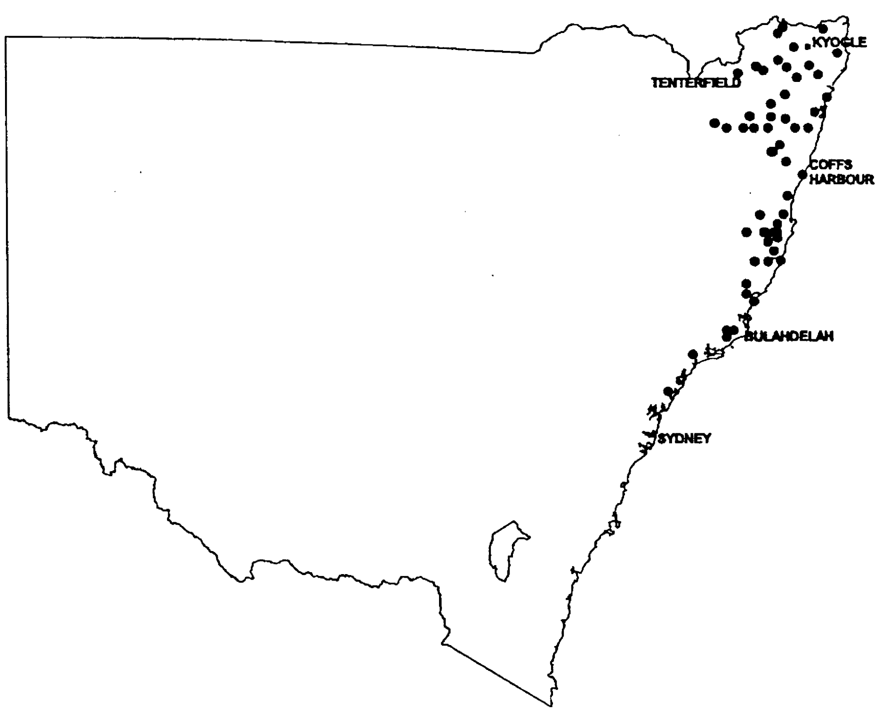
Echium plantagineum **(Paterson's curse)**
(also referred to as Salvation Jane)



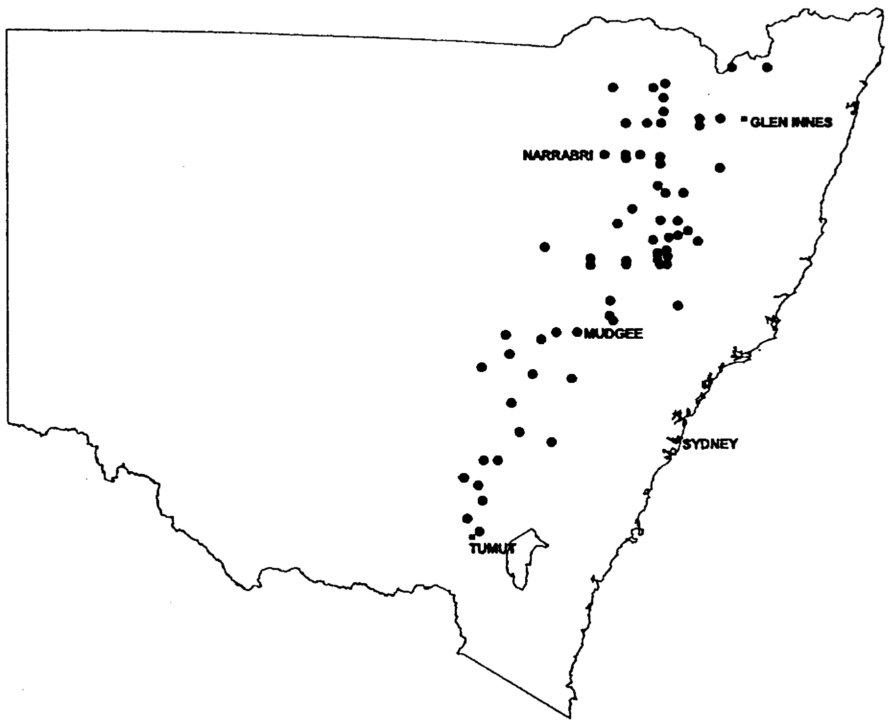
Echium vulgare (Viper's bugloss)



Eucalyptus acmenoides (White mahogany)

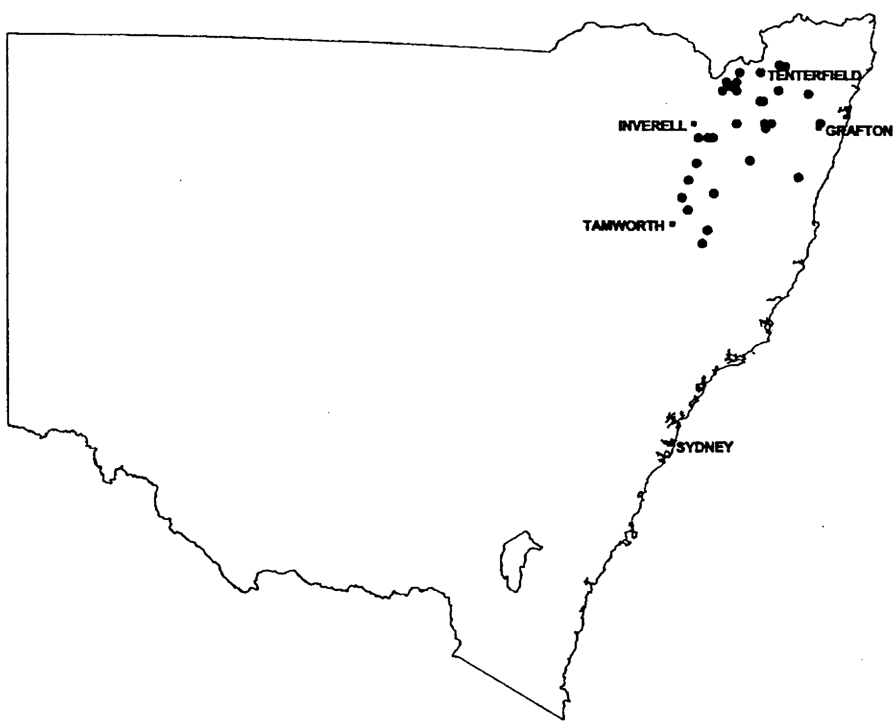


Eucalyptus albens (White box)

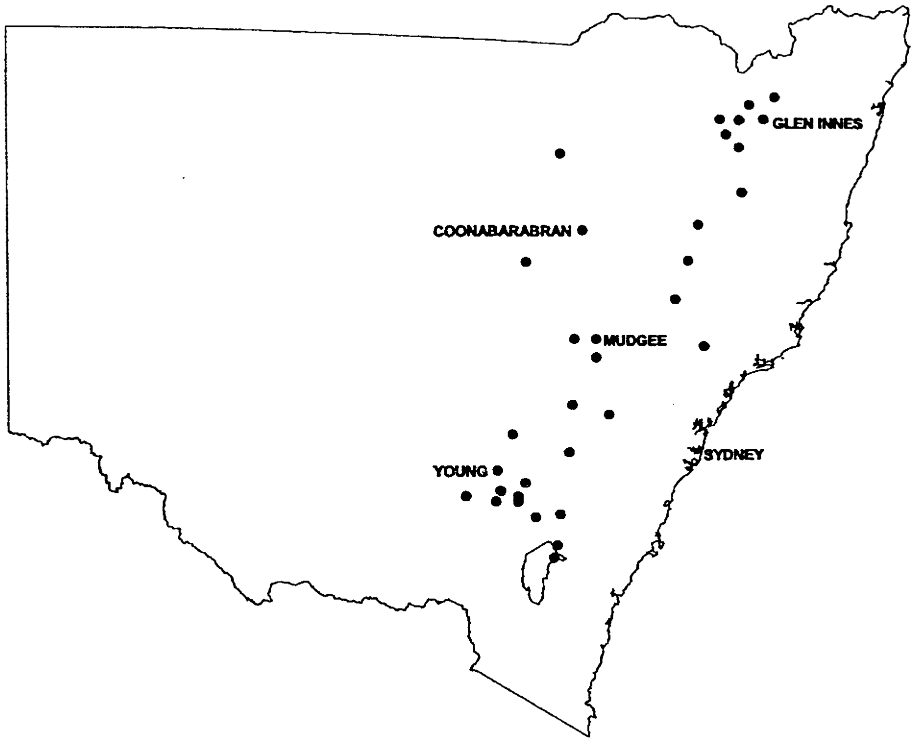


Eucalyptus andrewsii (New England blackbutt)

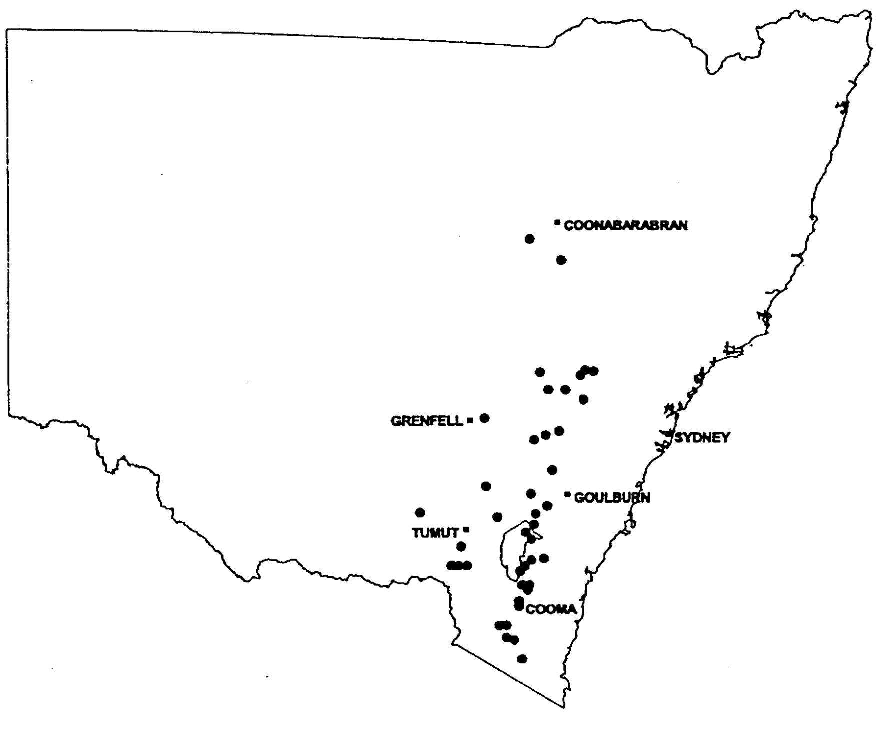
Both *E. andrewsii* sub species *andrewsii* and *E. andrewsii* subspecies *campanulata* are commonly known as New England blackbutt. Subspecies *andrewsii* is also referred to by beekeepers as Messmate.



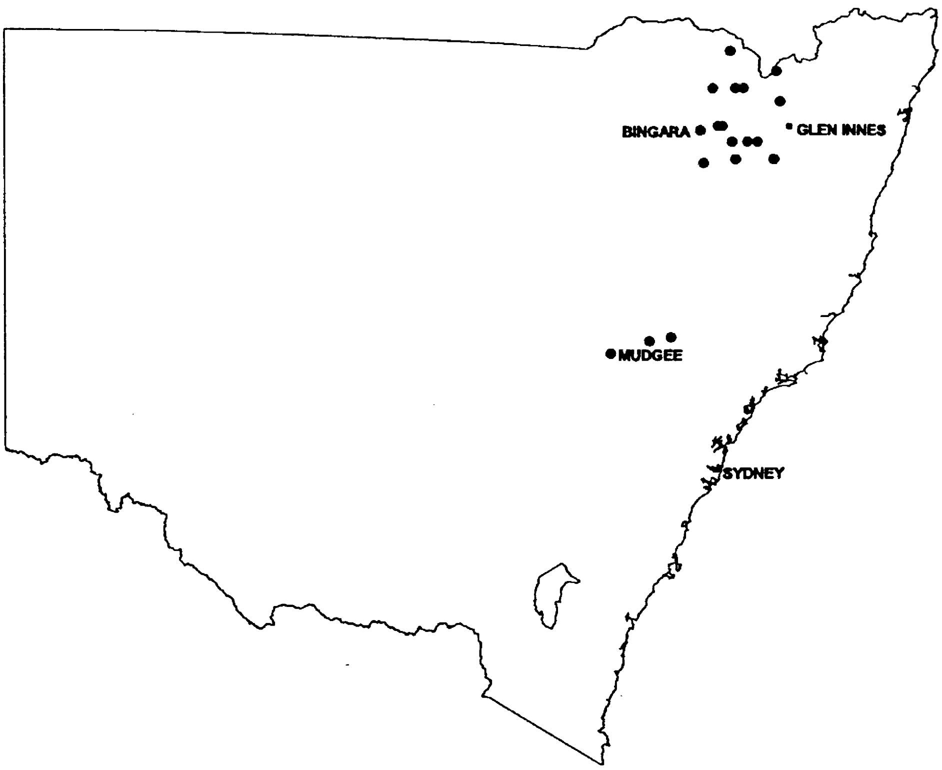
Eucalyptus blakelyi (Blakely's red gum)



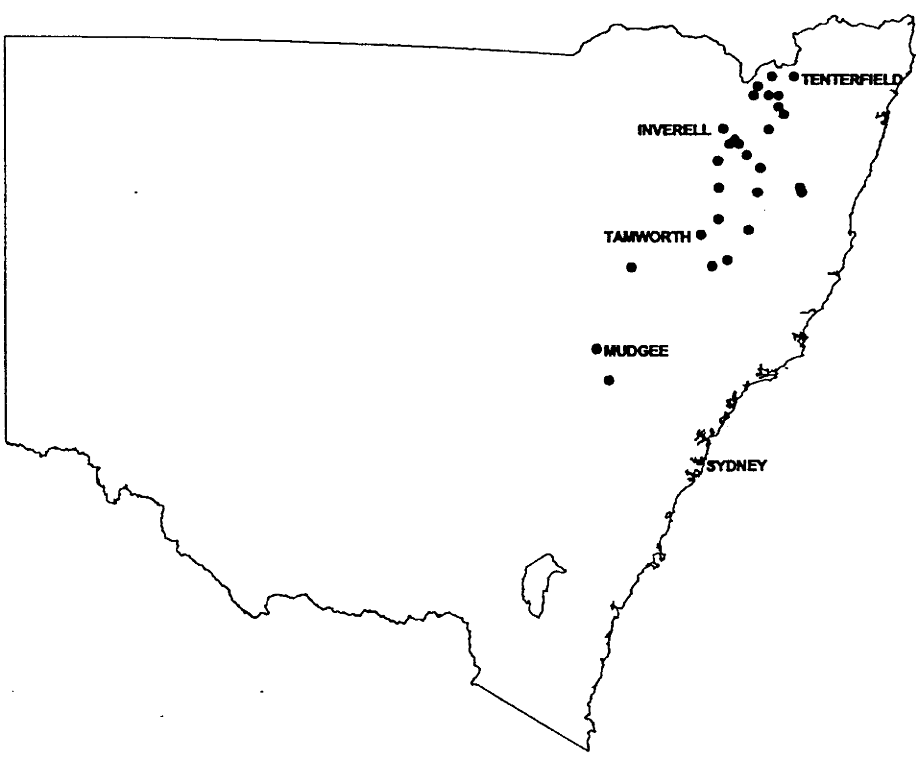
Eucalyptus bridgesiana (Apple box)



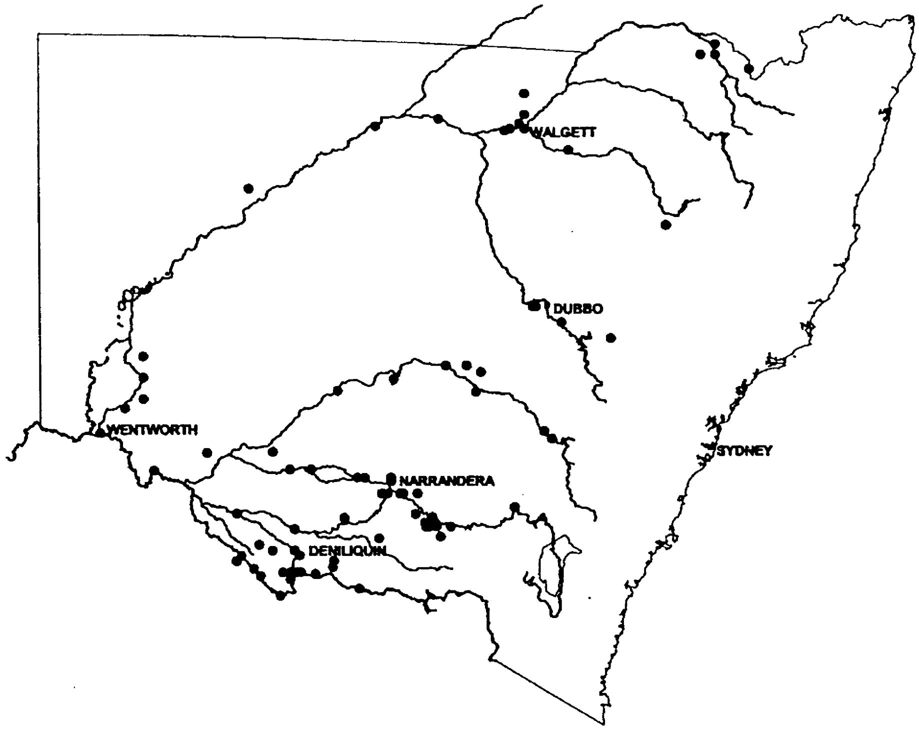
Eucalyptus caleyi (Caley's ironbark)



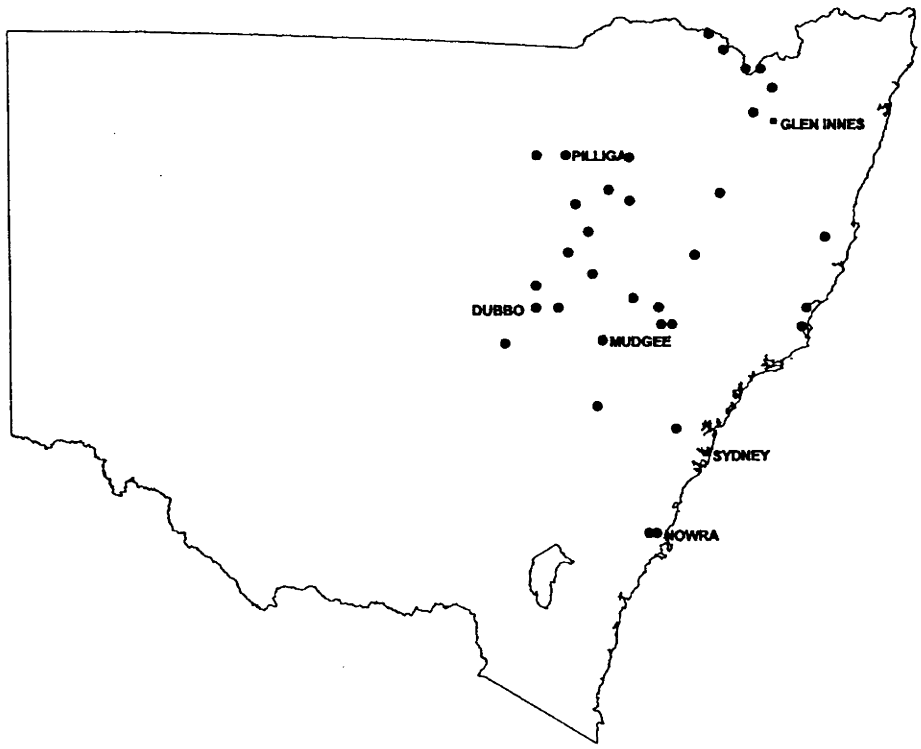
Eucalyptus caliginosa (Broad-leaved stringybark)



Eucalyptus camaldulensis **(Red river gum)**

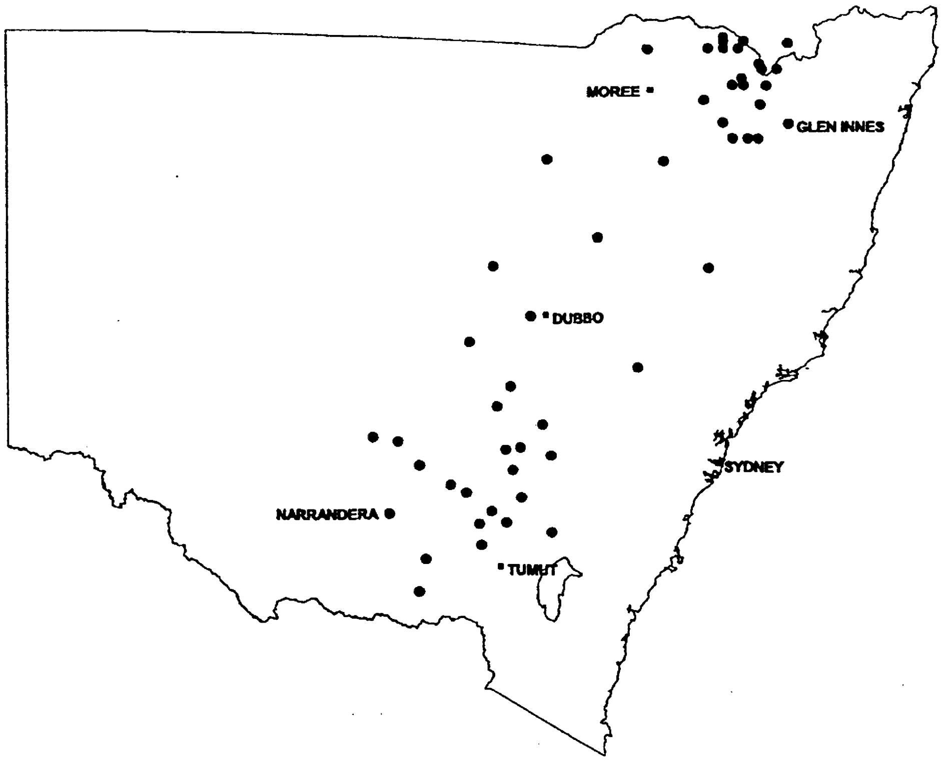


Eucalyptus crebra **(Narrow-leaved ironbark)**



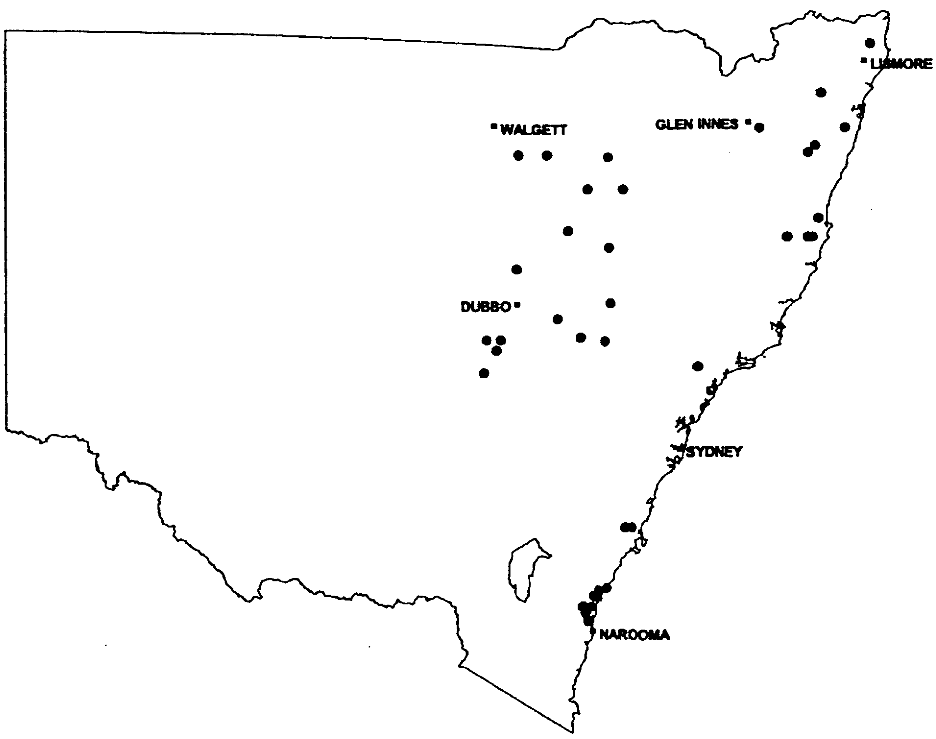
Eucalyptus dealbata (Hillgum)

(also called Smokey gum, Tumble down gum, Ridge gum, Sand gum)

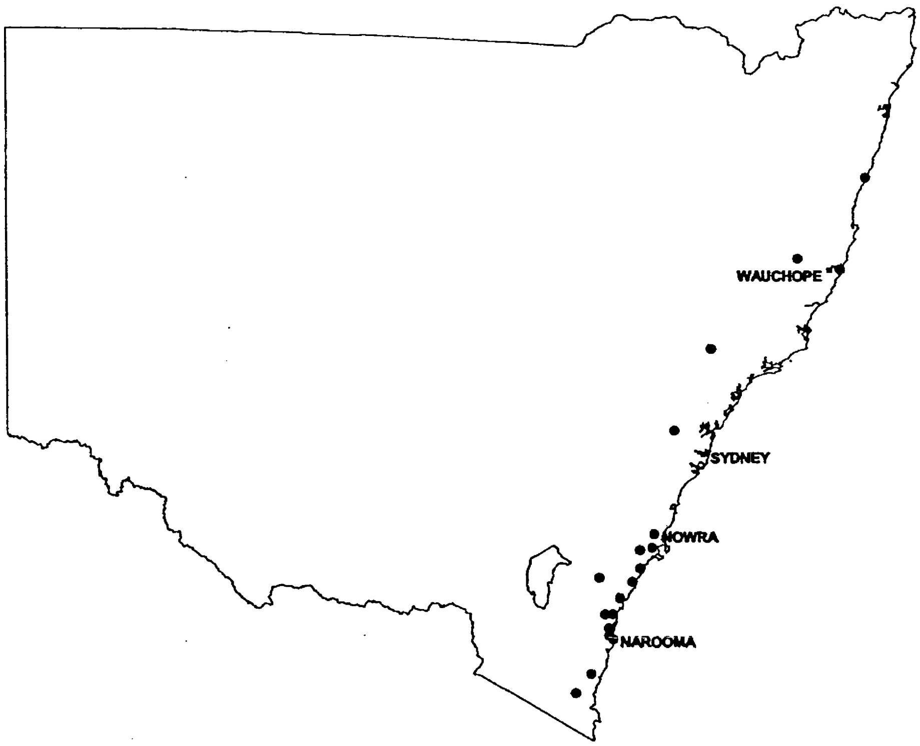


Eucalyptus fibrosa (Broad-leaved ironbark)

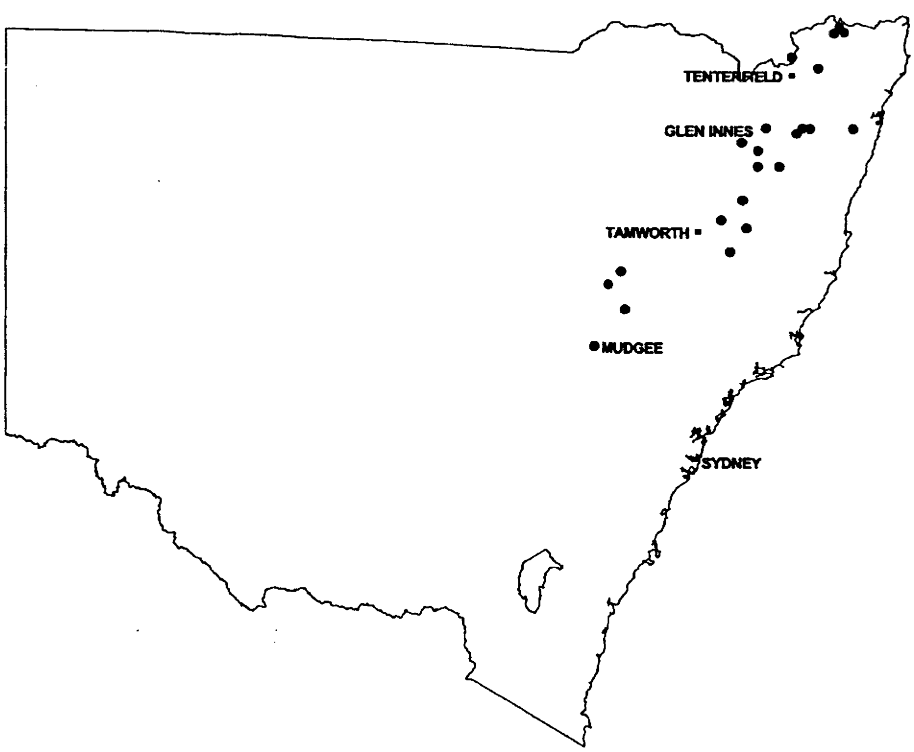
(also called Red ironbark)



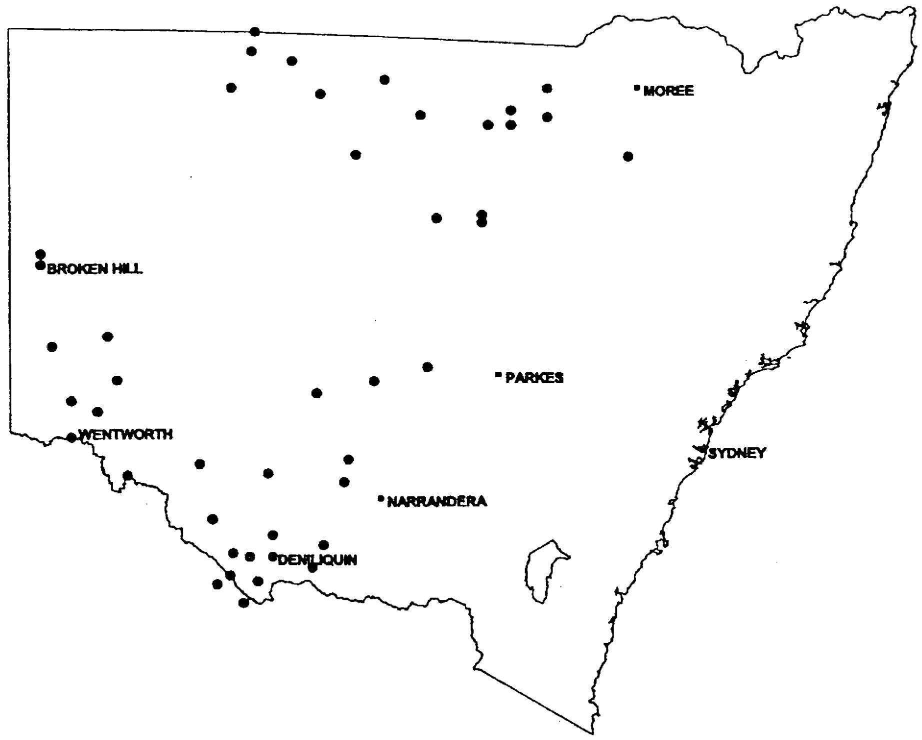
Eucalyptus globoidea (White stringybark)



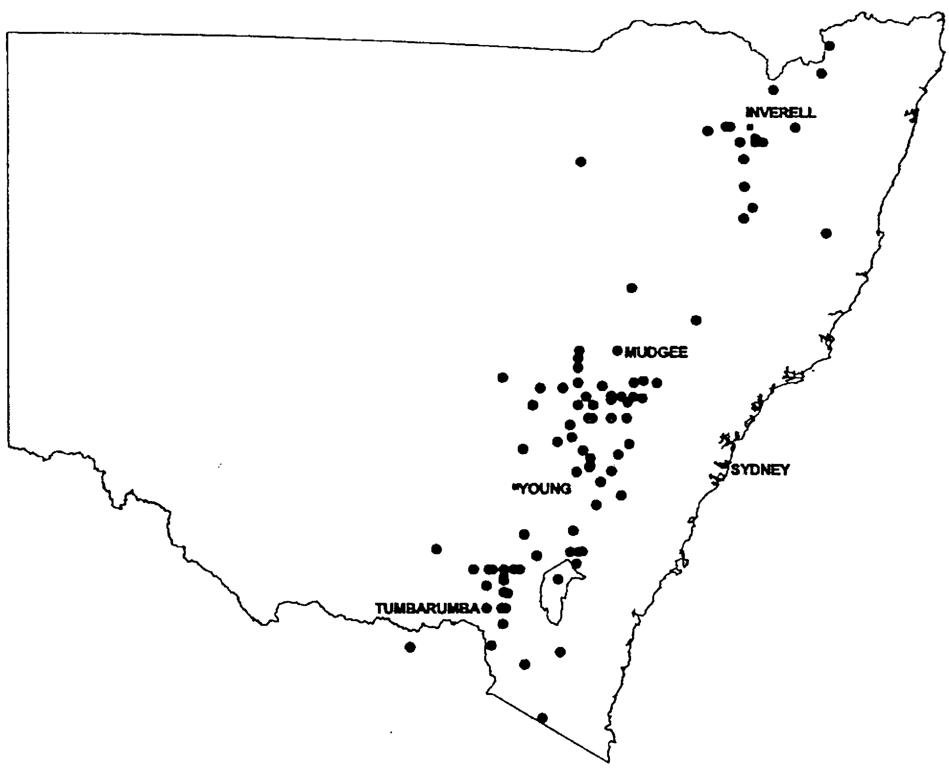
Eucalyptus laevopinea (Silver-topped stringybark)
(also referred to as Clean limb, White limb)



Eucalyptus largiflorens (Black box)

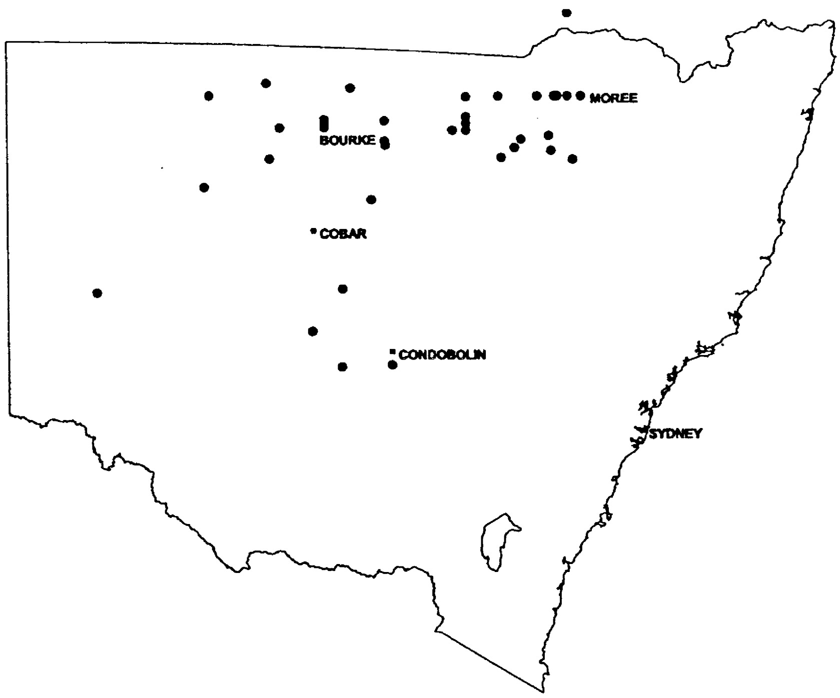


Eucalyptus macrorhyncha (Red stringybark)

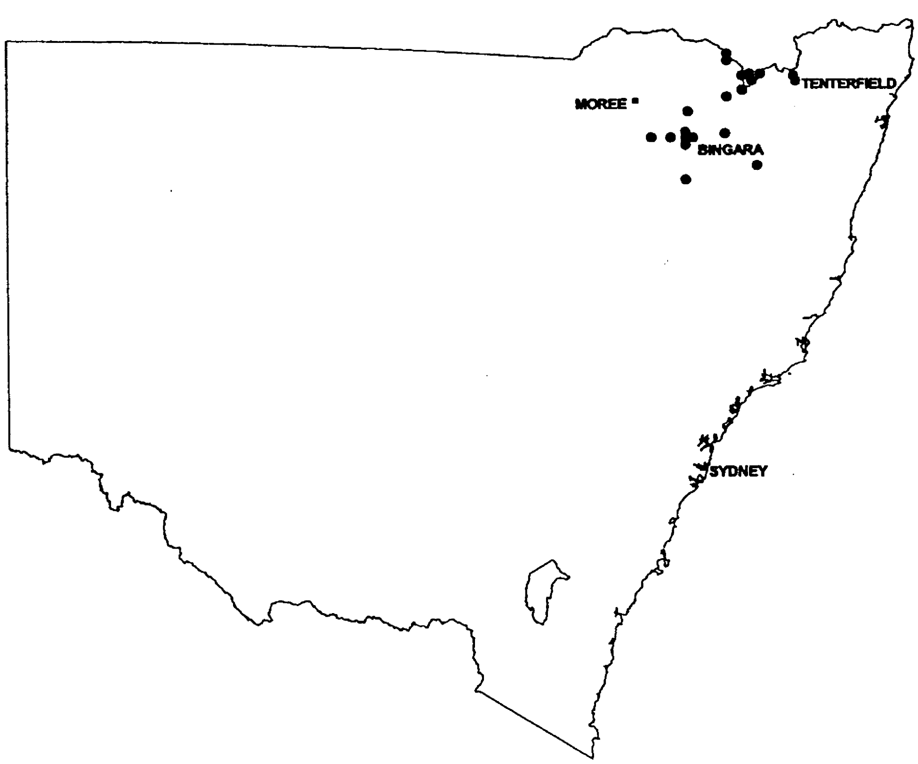


Eucalyptus microtheca (Coolibah)

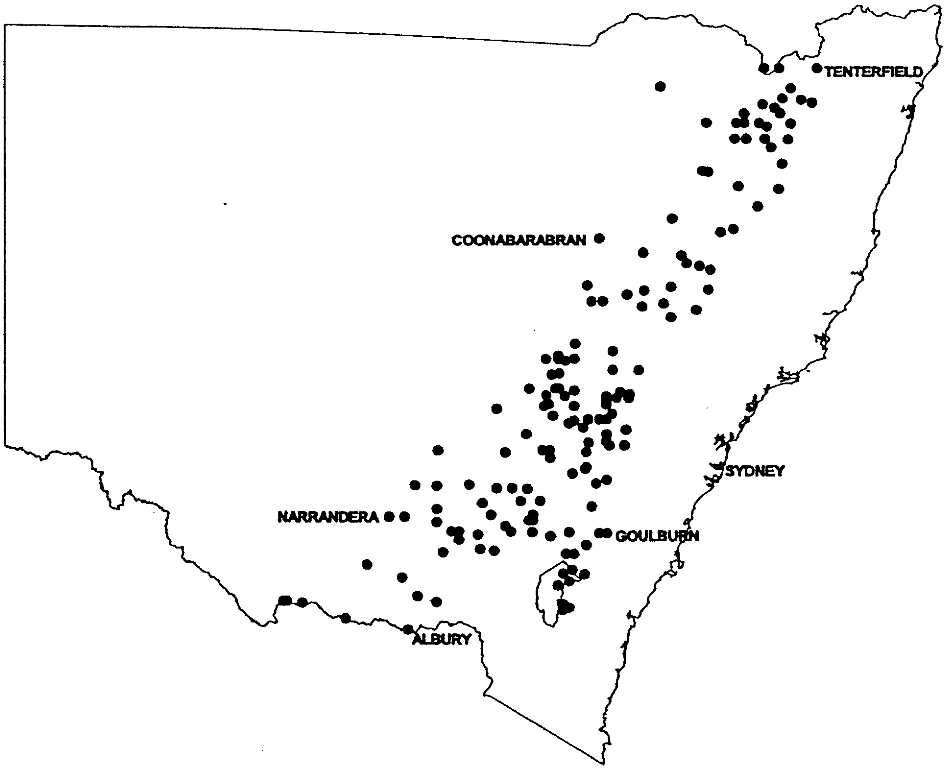
The common name "Coolibah" may refer to *Eucalyptus intertexta.* Their distributions overlap and thus, the use of common names makes it difficult to state absolutely which species each beekeeper is referring.



Eucalyptus melanophloia (Silver-leaved ironbark)

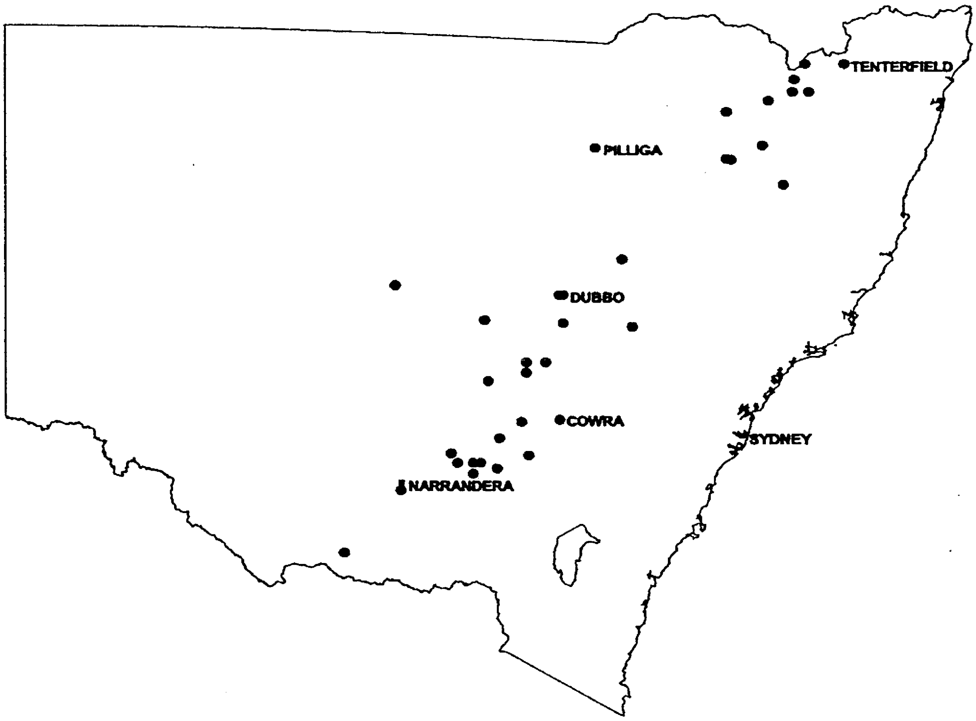


Eucalyptus melliodora (Yellow box)



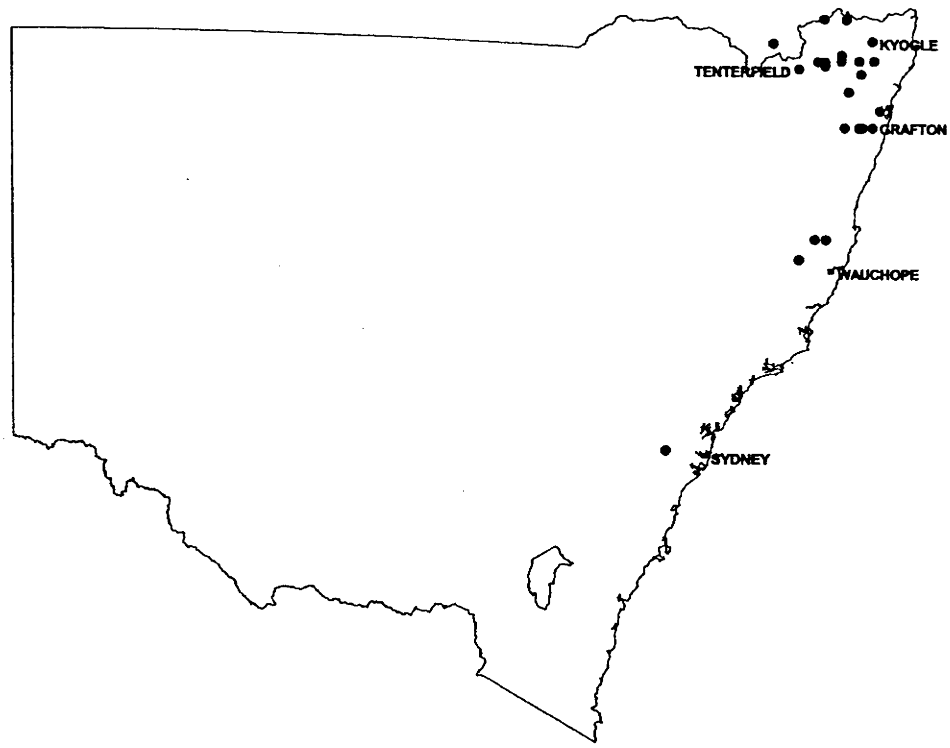
Eucalyptus microcarpa (Western grey box)

(also referred to as Brown box)

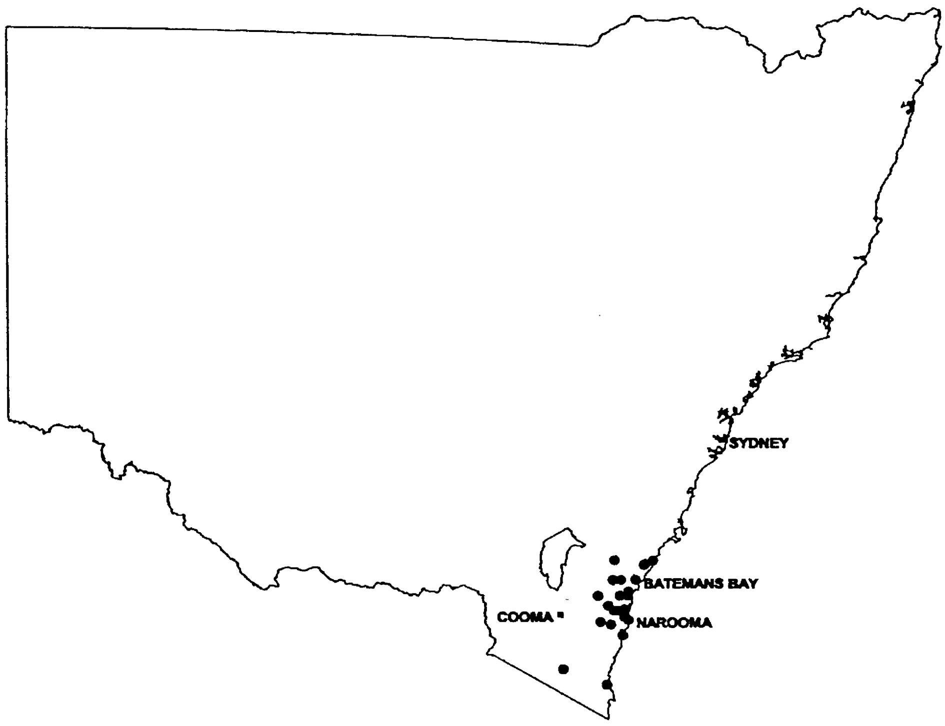


Eucalyptus moluccana **(Grey box)**

(also referred to as Gum topped box)

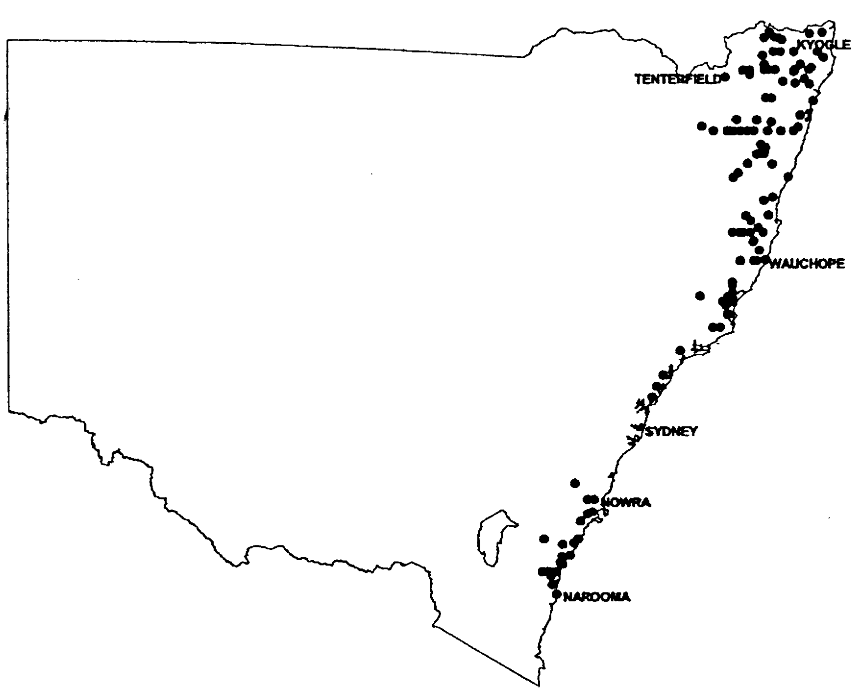


Eucalyptus muelleriana **(Yellow stringybark)**

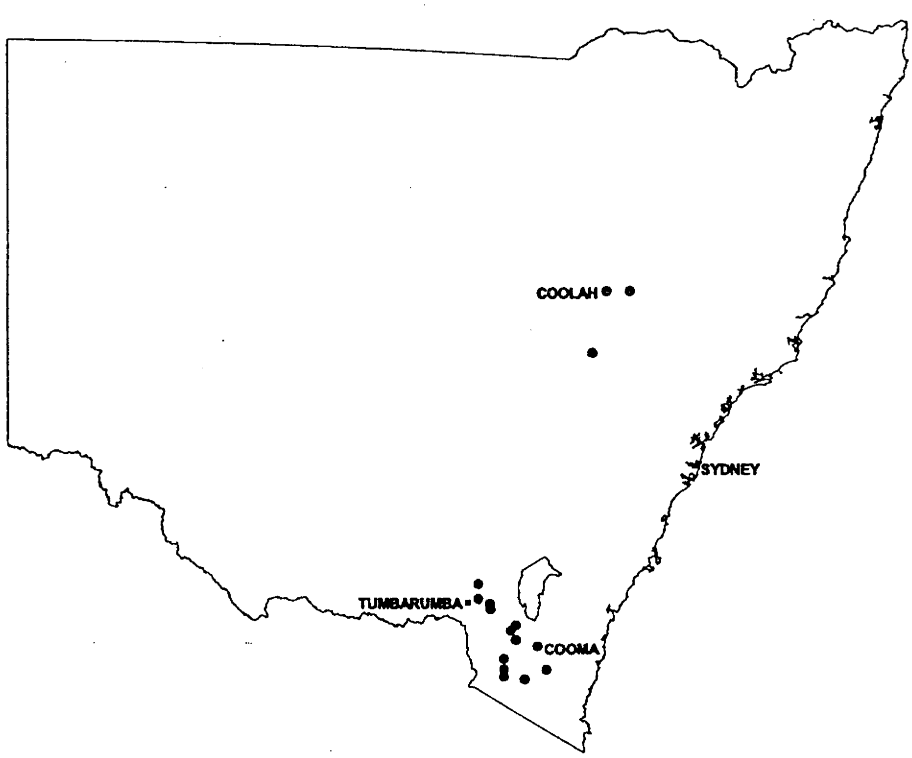


Eucalyptus paniculata (Grey ironbark)

The common name Grey ironbark may refer to two species in NSW, *Eucalyptus paniculata* and *E. siderophloia*. Both species are similar in the values for pollen and honey. *E. paniculata* is the more southerly species extending north to Coffs Harbour on the north coast.



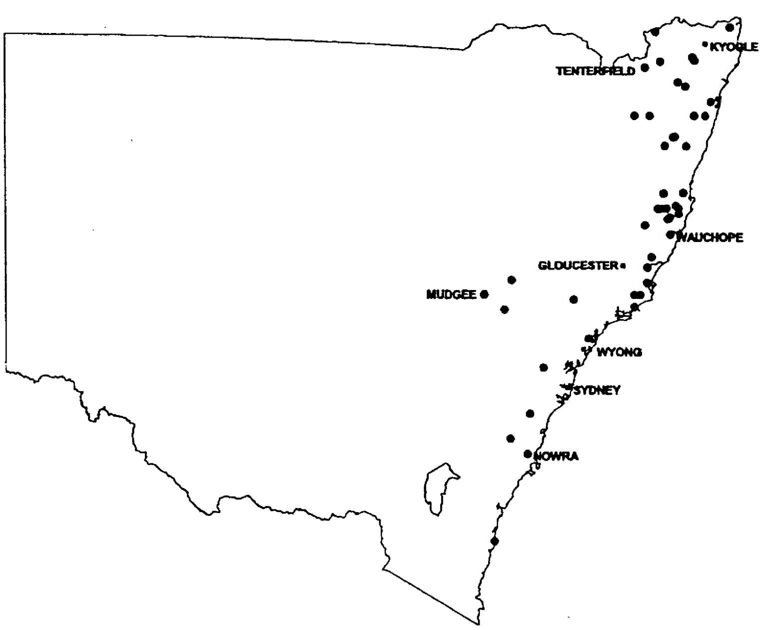
Eucalyptus pauciflora (Snow gum)



Eucalyptus pilularis (Blackbutt)

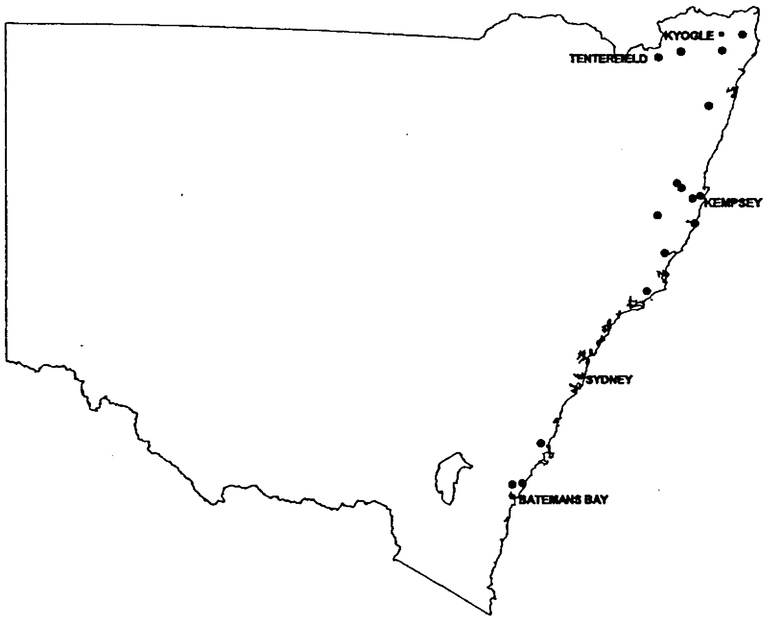
Eucalyptus propinqua/E. punctata (Grey gum)

The common name Grey gum can refer to Small fruited grey gum, *E. propinqua*, or Large fruited grey gum, *E. punctata*. In the responses 16 beekeepers listed Large fruited grey gum and 9 beekeepers listed Small fruited grey gum. Where Grey gum was stated, it was not possible with a high degree of confidence to sort them into individual species. Grey gums refer to, *E. canaliculata* (Dungog-Gloucester area), *E. biturbinata* (Gloucester to Kingaroy in QLD), *E. major* (SE QLD), *E. punctata* (Jervis Bay to Mudgee), *E. propinqua* (Wyong to SE QLD).

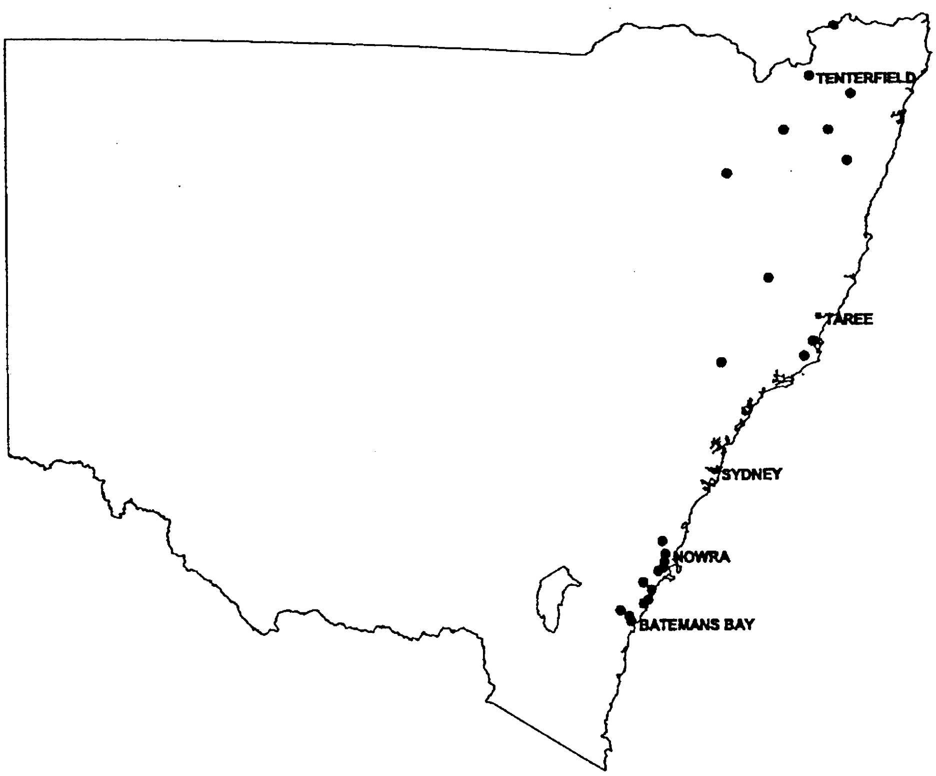


Eucalyptus resinifera (Red mahogany)

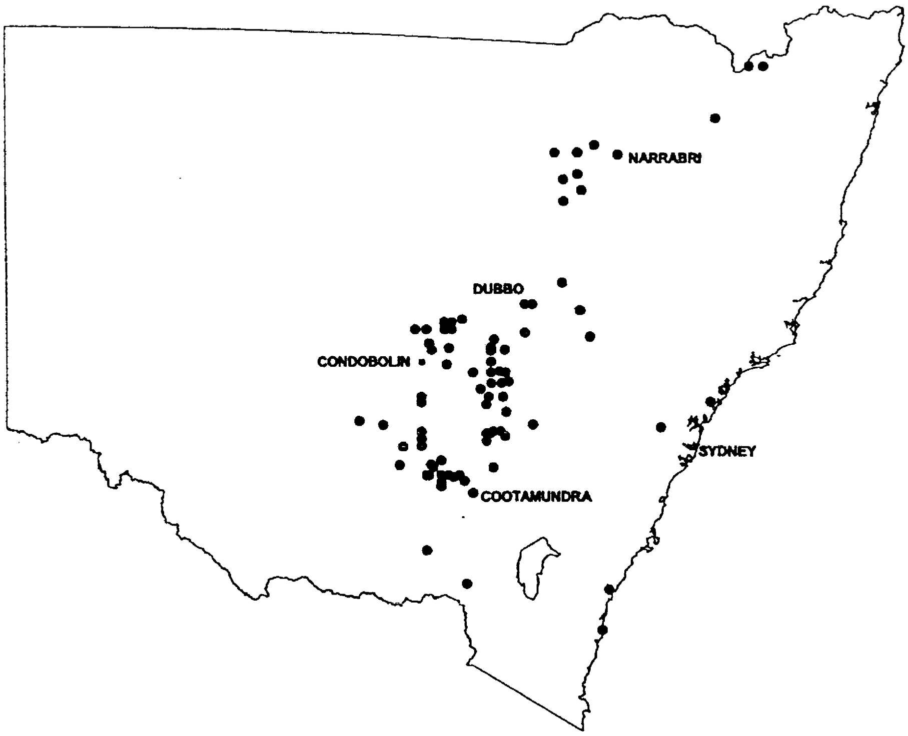
(also referred to as Red stringybark on the North Coast)



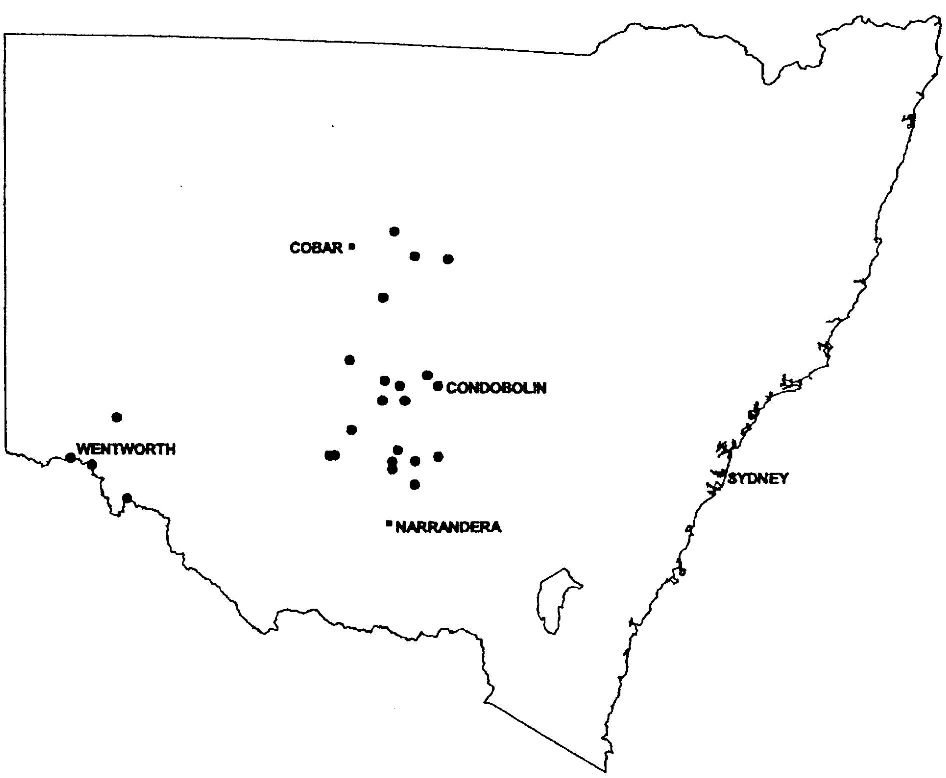
Eucalyptus saligna **(Sydney blue gum)**



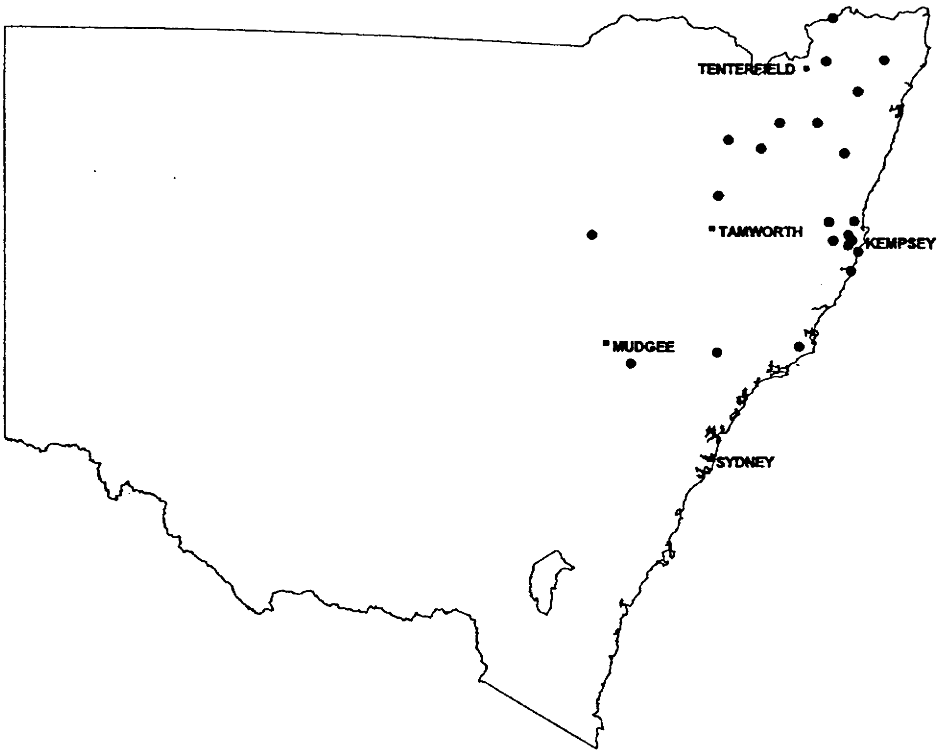
Eucalypts sideroxylon (Mugga ironbark)



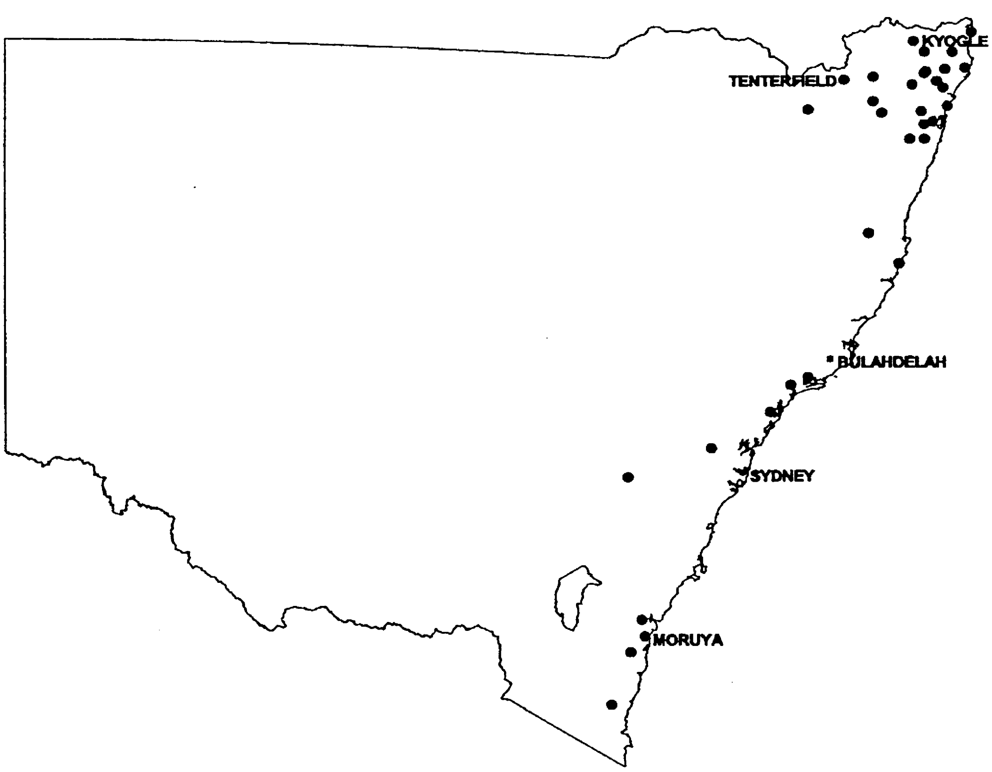
Eucalyptus socialis (Christmas mallee)



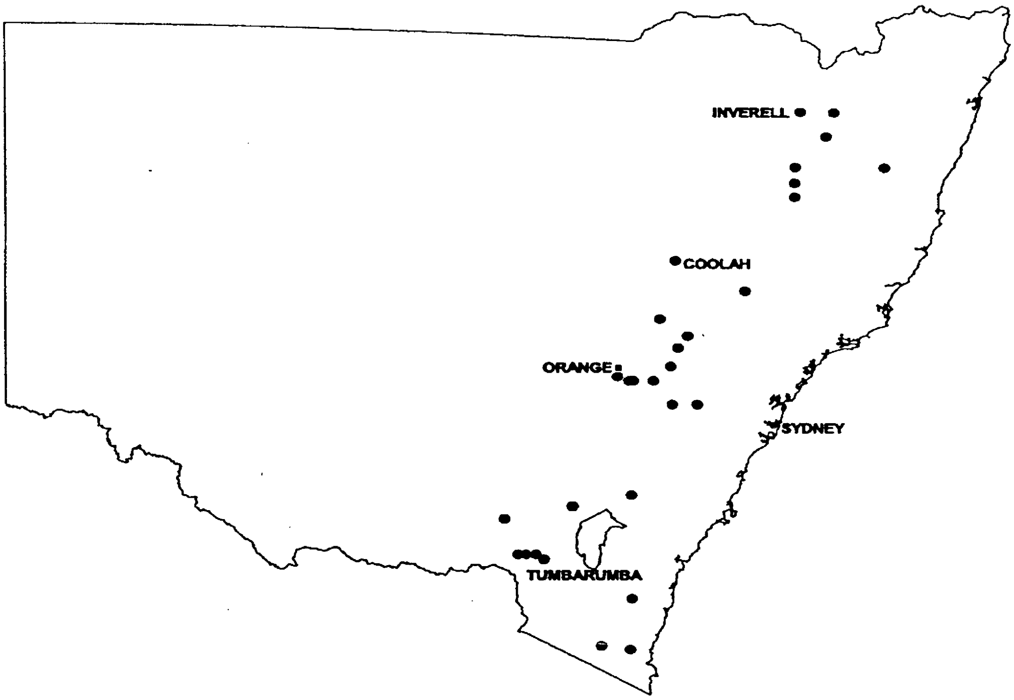
Eucalyptus spp. (Stringybark)



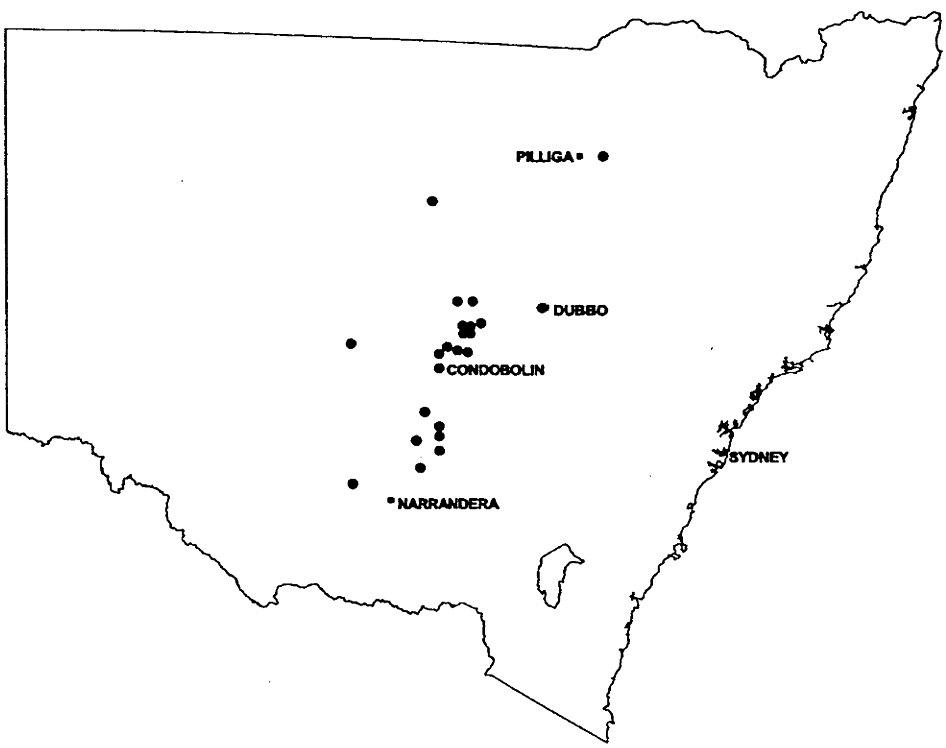
Eucalyptus tereticornis (Forest red gum)
(also referred to as Blue gum or Red gum)



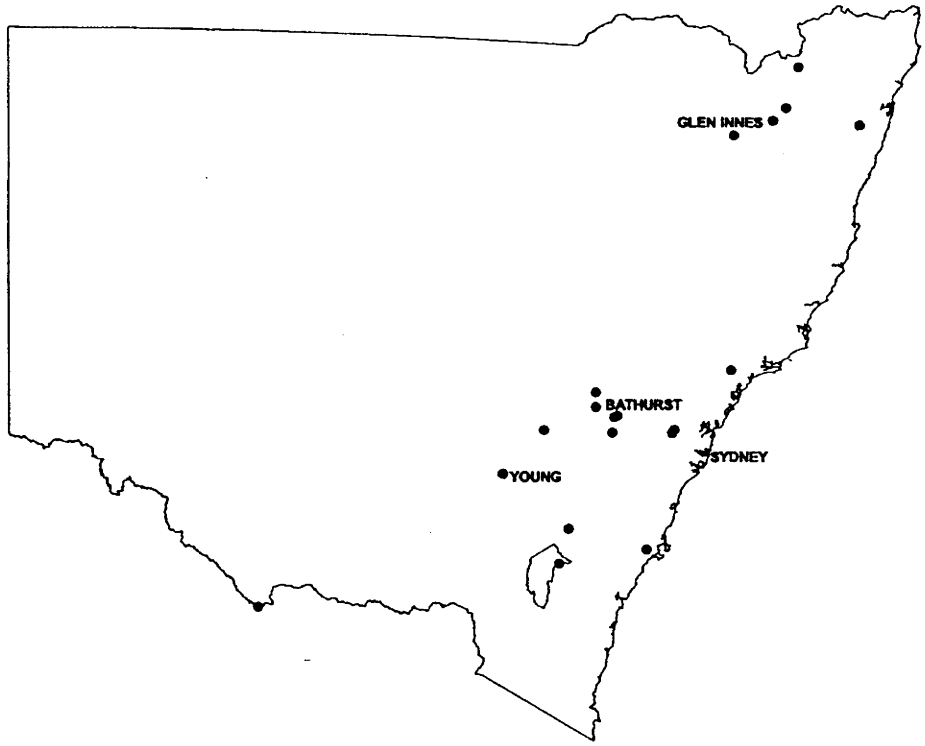
Eucalyptus viminalis **(Ribbon gum)**



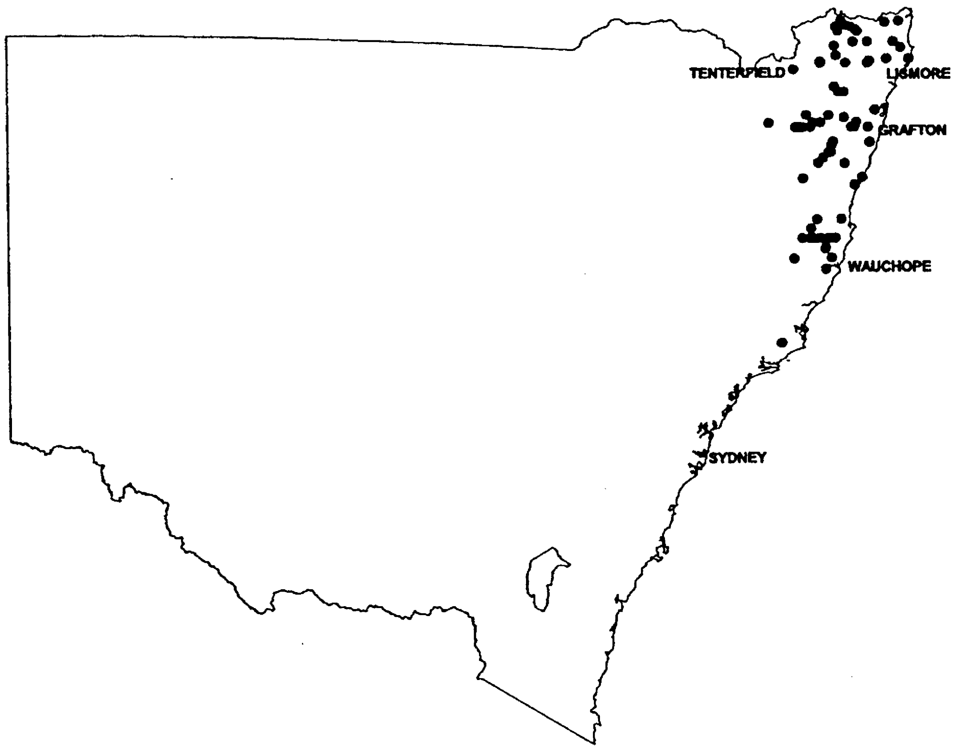
Eucalyptus viridis **(Green mallee)**



Hypochoeris radicata (Flatweed)

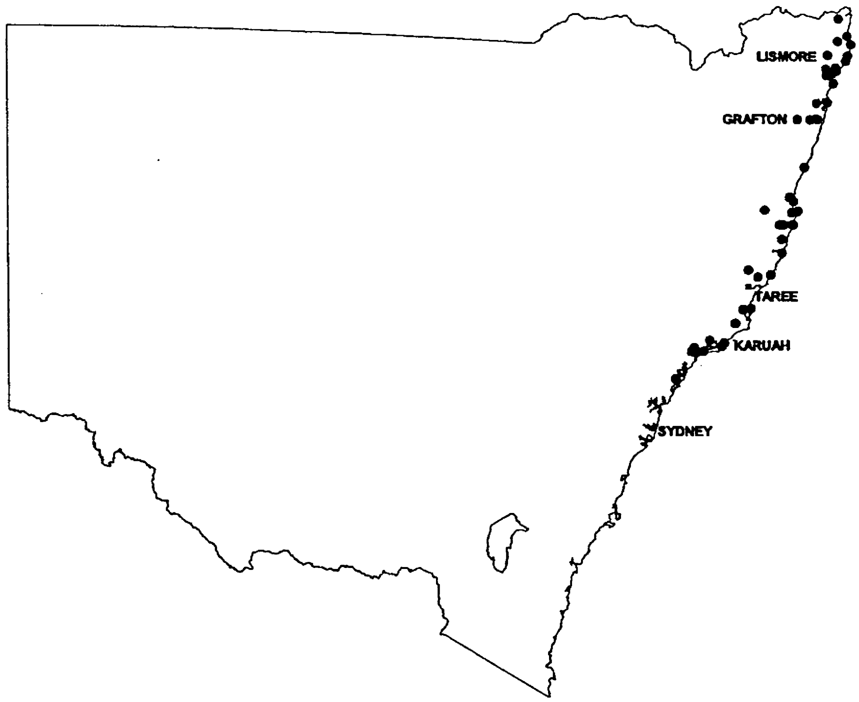


Lophostemon confertus (Brush box)

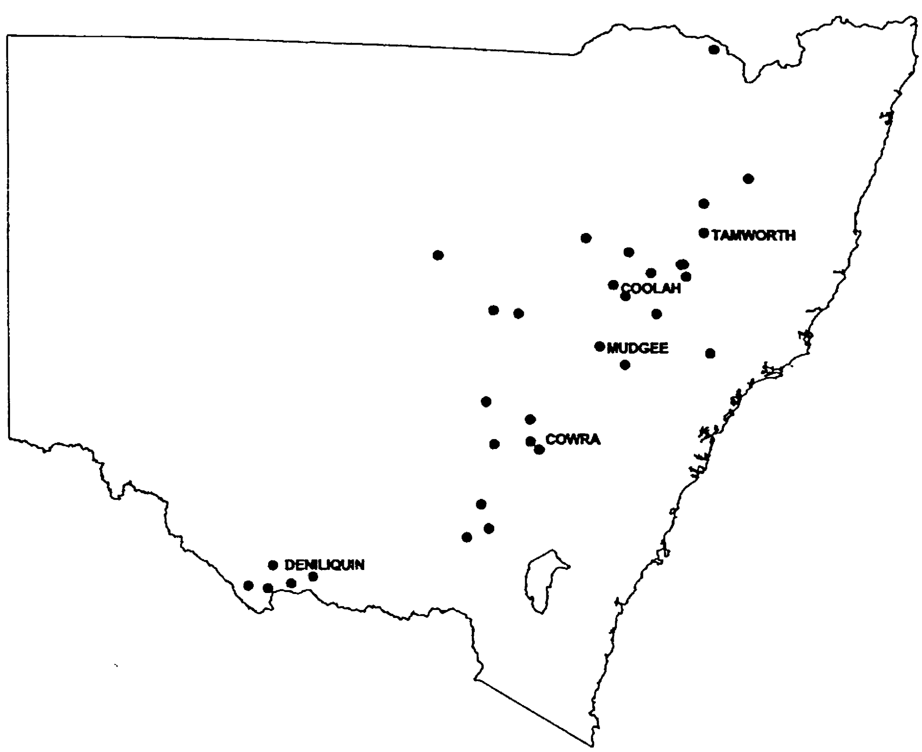


Melaleuca quinquenervia **(Broad-leaved tea tree)**

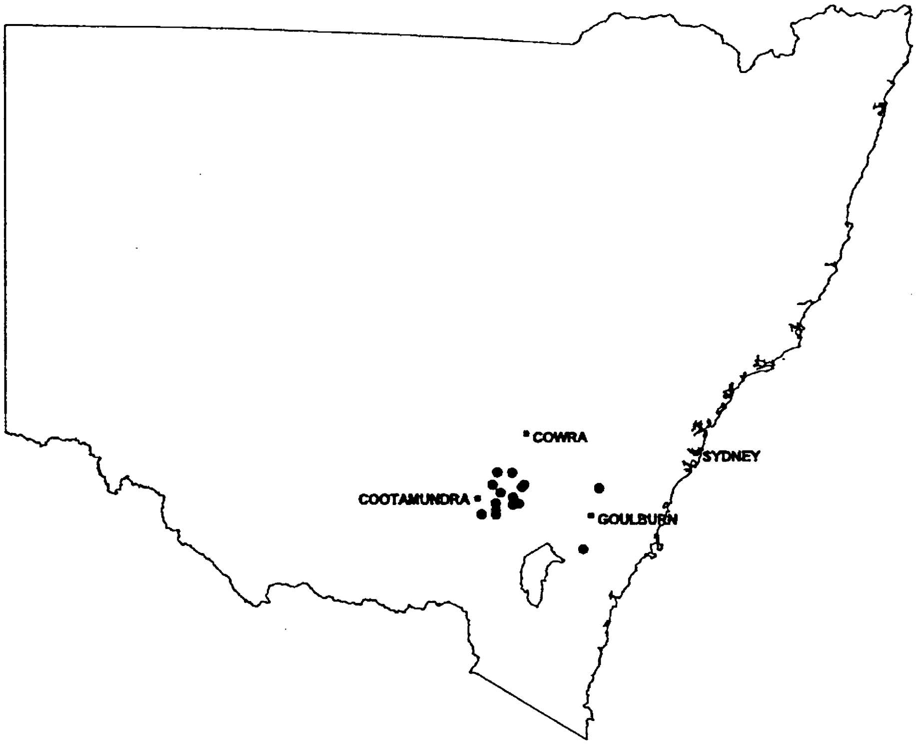
(also called Belbowrie)



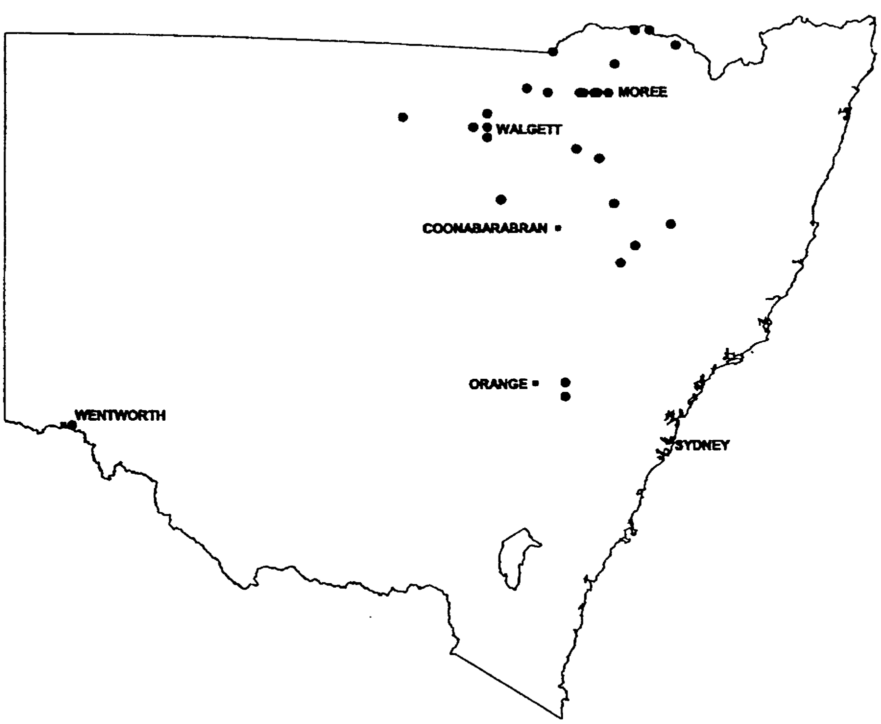
Medicago sativa **(Lucerne)**



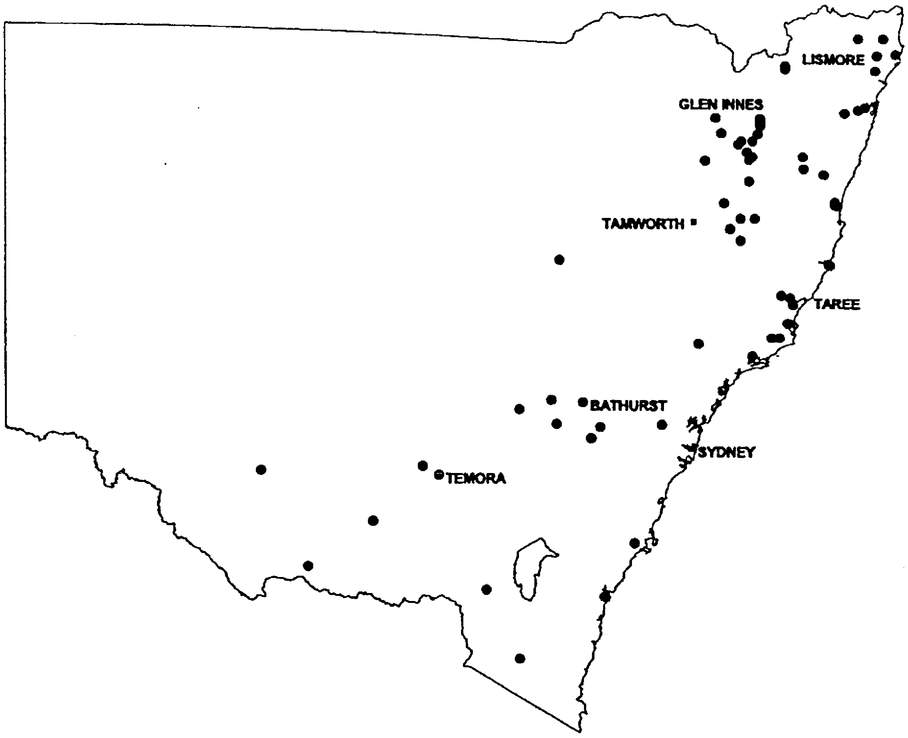
Onopordum acanthium (Scotch thistle)



Rapistrum rugosum (Turnip weed)



Trifolium repens (White clover)



APPENDIX 6

LOCATION AND DATE OF POLLEN PELLET COLLECTIONS (Chapter 7)

Number of *Echium plantagineum* pollen pellet samples collected by year and location .

Site	1995	1996	1997	Site	1995	1996	1997
Bathurst	2	0	0	Jugiong	1	0	1
Bethungra	1	0	0	Junee	1	0	0
Bimbi	0	0	4	Leneva Vic.	2	0	0
Breakfast Creek	2	0	0	Mingenew W.A.	0	1	0
Candelo	1	1	1	Molong	0	1	0
Canowindra	1	2	0	Nangus	1	0	0
Carcoar	1	0	0	Narrandera	1	1	1
Cowra	1	2	2	North Cowra	1	0	0
Darlington Point	1	1	0	S.E. Cowra	1	0	0
Dubbo	1	1	1	South Cowra	1	0	0
Goulburn	1	1	1	Stockinbingal	1	1	0
Greenthorpe	2	0	0	Tarana	1	0	0
Grenfell	1	0	0	W.A.	0	1	0
Harden	0	1	0	Wagga Wagga	1	0	0
Henry Lawson Drive	1	3	4	Woodstock	0	0	1

Botanical name	Location collected	Date collected	Chem. Lab.
Acacia doratoxylon	Dubbo	07-Oct-96	Vic.
Acacia longifolia	Nowra	24-Jul-96	NSW
Acacia spp.	Murrah SF	22-Aug-95	NSW
Acacia suaveolens	Shoalhaven	26-Jun-96	NSW
Angophora floribunda	Bega	19-Jan-96	NSW
Angophora floribunda	Bega	Jan-96	Vic.
Angophora floribunda	Bega	14-Jan-98	Vic.
Arctotheca calendula	Dubbo	09-Sep-96	Vic.
Asphodelus fistulosus	Carwarp, Vic.	Sep-96	Vic.
Banksia ericifolia	Shoalhaven	26-Jun-96	NSW
Banksia serrata	Nowra SF	28-Jan-97	Vic.
Brassica napus	Darlington Point	28-Aug-95	NSW
Brassica napus	Darlington Point	28-Aug-95	Vic.
Brassica napus	Woodstock	Sep-97	Vic.
Brassica napus	Stockinbingal	Nov-96	Vic.
Brassica napus	Ariah Park	12-Sep-95	NSW
Caduus nutans	Taralga	08-Feb-96	NSW
Carthamus lanatus	Taralga	08-Feb-96	NSW
Casuarina littoralis	Sussex Inlet	14-Jun-96	NSW
Casuarina littoralis	Sussex Inlet	25-Jun-96	NSW
Casuarina littoralis	Millingandi	Jun-96	NSW
Centaurea solstitialis	Molong	28-Jan-96	NSW
Chondrilla juncea	Yetholme	Jan-96	NSW
Chondrilla juncea	Leneva, Vic.	14-Feb-96	NSW
Cirsium vulgare	Taralga	Feb-96	NSW
Cirsium vulgare	Collector	Feb-97	Vic.
Cirsium vulgare	Black Springs	02-Feb-96	NSW
Citrus spp.	Paynters Siding	10-Nov-97	Vic.
Corymbia gummifera	Nowra	24-Mar-97	Vic.
Corymbia maculata	Moruya	Jul-97	Vic.
Corymbia maculata	Moruya	27-May-97	Vic.

Botanical name	Location collected	Date collected	Chem. Lab.
Corymbia maculata	Nowra SF	09-Jul-97	Vic.
Corymbia maculata	Bermagui	18-Jun-97	Vic.
Corymbia maculata	Moruya	Jul-97	Vic.
Corymbia maculata	Narooma	Jul-97	Vic.
Dillwynia spp.	Nowra	26-Sep-97	Vic.
Echium vulgare	Yetholme	Jan-96	Vic.
Eucalyptus albens	Blackville	29-Jun-96	NSW
Eucalyptus albens	Carroll	10-Jun-96	NSW
Eucalyptus albens	Carroll	Aug-96	NSW
Eucalyptus albens	Bigga	07-Aug-96	Vic.
Eucalyptus blakelyi	Jugiong	05-Dec-96	Vic.
Eucalyptus bridgesiana	Burra Creek	22-Mar-96	NSW
Eucalyptus bridgesiana	Ironmungie	04-Mar-96	NSW
Eucalyptus bridgesiana	Bombala	12-Mar-96	NSW
Eucalyptus bridgesiana	Bombala	12-Mar-96	Vic.
Eucalyptus bridgesiana	Williamsdale	12-Mar-96	NSW
Eucalyptus bridgesiana	Collector	Feb-97	Vic.
Eucalyptus camaldulensis	Narrandera	22-Dec-95	NSW
Eucalyptus camaldulensis	Darlington Point	Dec-96	Vic.
Eucalyptus delegatensis	Tumbarumba	20-Feb-96	NSW
Eucalyptus dumosa	West Wyalong	12-Feb-97	Vic.
Eucalyptus dumosa	Dubbo	20-Feb-98	Vic.
Eucalyptus fibrosa	Mogo	21-Feb-96	NSW
Eucalyptus globoidea	Nowra	26-Sep-97	Vic.
Eucalyptus longifolia	Murrah SF	28-Jun-95	NSW
Eucalyptus longifolia	Millingandi	Jun-96	NSW
Eucalyptus macrorhyncha	North Orange	Feb-96	NSW
Eucalyptus macrorhyncha	Abercrombie Caves	Mar-96	NSW
Eucalyptus macrorhyncha	Tumbarumba	25-Feb-98	Vic.
Eucalyptus macrorhyncha	Oberon	23-Feb-97	Vic.
Eucalyptus mannifera	Bungonia	24-Mar-97	Vic.
Eucalyptus mannifera	Oberon	16-Apr-97	Vic.

Botanical name	Location collected	Date collected	Chem. Lab.
Eucalyptus microcarpa	Flagstaff	26-Mar-97	Vic.
Eucalyptus polyanthemos	Bigga	26-Sep-96	Vic.
Eucalyptus punctata	Nowra SF	28-Jan-97	Vic.
Eucalyptus robusta	Jervis Bay	03-Sep-96	NSW
Eucalyptus saligna	Termeil	06-Mar-97	Vic.
Eucalyptus sclerophylla	Nowra SF	24-Mar-97	Vic.
Eucalyptus socialis	Weethale	23-Dec-96	Vic.
Eucalyptus viminalis	Nimmitabel	12-Mar-96	NSW
Fagopyrum esculentum	Black Springs	10-Jan-98	Vic.
Hakea sericea	Nowra	02-Aug-96	NSW
Helianthus annuus	Griffith	20-Jan-96	NSW
Helianthus annuus	Griffith	16-Jan-97	Vic.
Hypochoeris radicata	Oberon	03-Jan-98	Vic.
Hypochoeris radicata	Bungonia	10-Nov-97	Vic.
Hypochoeris radicata	Goulburn	24-Dec-98	Vic.
Hypochoeris radicata	Molong	16-Nov-96	Vic.
Hypochoeris radicata	Tarago	27-Jan-96	Vic.
Hypochoeris radicata	Black Springs	02-Feb-96	NSW
Hypochoeris radicata	Amaroo	Jan-96	NSW
Hypochoeris radicata	Bathurst	Jan-98	Vic.
Hypochoeris radicata	Weethale	14-Jan-97	Vic.
Lavandula spp.	Goulburn	24-Dec-98	Vic.
Lupinus angustifolius	Boree Creek	15-Sep-97	Vic.
Lupinus angustifolius	Sandigo	09-Sep-98	Vic.
Papilionaceae spp.	Nowra	26-Sep-97	Vic.
Papilionaceae spp.	Nowra SF	11-Sep-96	NSW
Papilionaceae spp.	Nowra SF	Sep-97	Vic.
Prunus dulcis	Darlington Point	20-Aug-95	NSW
Prunus dulcis	Mildura, Vic.	01-Sep-96	NSW
Pyrus connunis	Goulburn Valley, Vic.	Oct-97	Vic.
Rapistrum rugosum	Paynters Siding	30-Oct-95	NSW
Rapistrum rugosum	Mildura, Vic.	01-Sep-96	NSW

Botanical name	Location collected	Date collected	Chem. Lab.
Rapistrum rugosum	Coonamble	Aug-96	NSW
Rapistrum rugosum	Dirranbandi, Qld.	Aug-96	NSW
Rapistrum rugosum	Walgett	21-Aug-96	Vic.
Salix discolor	Lithgow	06-Sep-95	NSW
Salix fragilis	Tarana	12-Sep-95	NSW
Salix fragilis	Goulburn	07-Sep-95	NSW
Senecio madagascariensis	Nowra	03-Sep-96	NSW
Sisymbrium officinale	Goulburn	17-Nov-95	NSW
Sisymbrium officinale	Tarago	Feb-96	NSW
Sisymbrium officinale	Goulburn	12-Feb-96	NSW
Trifolium balansae	Wagga Wagga	17-Oct-95	NSW
Trifolium balansae	Ariah Park	04-Oct-96	Vic.
Trifolium repens	Candelo	01-Nov-96	Vic.
Ulex europaeus	Collector	27-Aug-96	NSW
Vaccinium spp.	Gunning	Sep-95	NSW
Vicia faba	Darlington Point	28-Aug-95	NSW
Vicia spp.	Boree Creek	28-Sep-95	NSW
Vicia spp.	Sandigo	28-Sep-95	NSW
Zea mays	Darlington Point	11-Jan-96	NSW
Unidentified	Tumbarumba	20-Feb-96	NSW
Unidentified	Amaroo	Jan-96	NSW
Unidentified	Black Springs	2-Feb-96	NSW
Unidentified	Hungerford, Qld.	28-Jul-96	NSW
Unidentified	Nowra	11-Sep-96	NSW
Unidentified	Nowra	24-Mar-97	Vic.